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Prevention of Dust Explosions In Grain Elevators— An Achievable Goal

A Task
Force
Report

United States
Department of
Agriculture

Office of the
Special Coordinator
for Grain Elevator
Safety and Security

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ABSTRACT

In response to the problems of dust fires and explosions in U.S. grain handling facilities, a special USDA Task Force prepared this report for the Secretary of Agriculture. The report recommends possible solutions which could increase overall safety in grain handling facilities and reduce the numbers of fire and explosion incidents. Although the ideal result would be complete elimination of these hazards, achieving this depends on how effectively solutions are implemented.

The report emphasizes that grain dust must be removed and not reintroduced during grain handling. In conjunction with this, additional recommendations stress the need for additional research and increased levels of housekeeping, maintenance, and safety programming in all U.S. grain handling facilities. The report also recommends the development of mechanisms to promote technology transfer and increased coordination and cooperation among industry and government.

The report reviews the history of grain dust fires and explosions, analyzes information concerning 250 explosions, and surveys U.S. grain exporting facilities.

The report details recent Federal, State, and local investigative and enforcement procedures related to grain dust fires and explosions. Also included are descriptions and evaluations of major points developed during the International Symposium on Grain Elevator Explosions as well as a listing of USDA research activities. The report also includes four separate studies concerning various aspects of grain dust explosion phenomena.

* * * * *

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PREFACE

Grain elevator fires and explosions have generated considerable interest and concern. During the last few years, grain dust explosions with their attendant loss of lives and property have created an atmosphere of urgency. Finding an immediate solution to these fires and explosions is imperative.

Many Federal agencies have varying degrees of responsibility and jurisdiction in the grain industry. The U.S. Department of Agriculture (USDA) certifies the weight and quality of exported grain and is responsible for the health and safety of its employees working in export grain facilities. The Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor has broad jurisdiction for safety in the workplace. The National Institute of Occupational Safety and Health (NIOSH) of the U.S. Department of Health, Education, and Welfare (HEW) is required by law to assist OSHA in the development and issuance of regulations to maximize safety in the workplace. The Food and Drug Administration of HEW regulates the use of pesticides, fumigants, and chemicals or other substances affecting the character, taste, color, and sanitation of grain. The Environmental Protection Agency (EPA) monitors and regulates environmental quality including the emission of grain dust into the air. Add the investigative authorities of the Federal Bureau of Investigation (FBI), the Bureau of Alcohol, Tobacco and Firearms (AT&F) of the U.S. Treasury, plus various State and local agencies, and a bewildering picture of overlapping responsibilities and conflicting jurisdictions emerges. It is readily apparent that no single agency or entity has total authority, jurisdiction, or responsibility for the grain industry—an industry which encompasses over 15,000 off-farm grain handling facilities.

This report details a number of approaches suggested by investigators for solving the problem of grain dust explosions. There are solutions offered that require substantial time to test and implement. There are additional solutions offered which do address the symptoms, but not the causes of explosions. The Task Force agrees with, and supports, many of the conclusions and recommendations offered. It is our conclusion, however, that the immediate implementation of existing technology that will remove the smaller dust particles and prohibit the recirculation of these fines will reduce the amount of fuel available for explosions. The use of mechanical dust collection equipment and proper maintenance and housekeeping is a practical, economically feasible approach that would not disrupt the vital flow of grain. These recommended actions are likely to show immediate and dramatic results.

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FOREWORD

Dust explosions have occurred and been recorded in grain handling facilities for almost 200 years. Statistics available for the past two decades emphasize both the tragic magnitude and the urgency of this problem.

In the last 21 years there have been at least 250 dust explosions in grain elevators and feed mills in the United States. The losses have been great with at least 164 deaths, 605 injured, and hundreds of millions of dollars worth of property destroyed. In the recent past, a series of explosions vividly reiterated the need to reduce the hazards in grain elevators and feed mills.

In early 1976, two explosions killed 14, injured 20 and began a catastrophic sequence of incidents which culminated in seven grain elevator and feed mill explosions in the short span of 2 months: December 1977 and January 1978. These seven explosions accounted for the loss of 62 lives, 55 injuries, and a direct property loss of millions of dollars. In two of those explosions 13 USDA employees were killed and 4 were injured. For the remainder of 1978, there were 11 additional grain dust explosions.

Hazardous conditions in handling facilities raise the spectre of curtailment of grain exports. Any serious disruption of our grain trade would have an adverse effect on the American balance of payments. On January 25, 1978, Secretary of Agriculture Bob Bergland, reflecting the concern of the Department, the White House, and the Congress, asserted a positive leadership role for USDA by announcing an immediate and continuing effort to find the causes of and cures for grain dust explosions.

This report is one of the products of the Special Task Force on Grain Elevator Safety and Explosions. The Task Force was organized in response to the Secretary's mandate to initiate an affirmative program to reduce the hazards of explosions. The report contains information on 250 explosions that have occurred in the last 21 years. This represents the most comprehensive attempt to investigate explosions in their totality, and the relationship one has to another in an attempt to find a common denominator. It also includes detailed information concerning most of the export elevators in the United States and in some foreign countries, specifically detailing dust control, construction equipment, storage capacity, products handled, facility operations, safety plans, and other material. Much of the information reported is being presented for the first time.

The report also details findings and recommendations about the adequacy of past investigations, elevator operations, emergency preparedness, scientific research, enforcement of known preventive measures and the liaison between Government and industry.

This report does not attempt to fix culpability for past explosions. Its objective is to learn from the past in order to improve the safety, health, and

security of all who now are involved with grain elevators and feed mills. We gratefully acknowledge the invaluable contributions of many individuals and organizations both within and outside USDA.

John V. Graziano

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ABBREVIATIONS

Agricultural Marketing Service (AMS)
Association of American Railroads (AAR)
Bureau of Alcohol, Tobacco and Firearms (AT&F)
Defense Civil Preparedness Agency (DCPA)
Department of Housing and Urban Development (HUD)
Environmental Protection Agency (EPA)
Federal Bureau of Investigation (FBI)
Federal Disaster Assistance Administration (FDAA)
Federal Grain Inspection Service (FGIS)
Food and Drug Administration (FDA)
Foreign Agricultural Service (FAS)
Government Printing Office (GPO)
National Academy of Sciences (NAS)
National Fire Protection Association (NFPA)
National Grain and Feed Association (NGFA)
National Information Center (NIC)
National Institute of Occupational Safety and Health (NIOSH)
National Materials Advisory Board (NMAB)
National Oceanic and Atmospheric Administration (NOAA)
Occupational Safety and Health Administration (OSHA)
Office of the Special Coordinator for Grain Elevator Safety and Security (OSC)
Relative Humidity (R.H.)
Science and Education Administration (SEA)
Transportation and Warehouse Division (T&W)
United States (U.S.)
United States Department of Agriculture (USDA)
United States Department of Health, Education, and Welfare (HEW)

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Chapter 1

SUMMARY OF RECOMMENDATIONS

This chapter contains a summary of all of the recommendations found in the report. These recommendations are listed by chapter. In some cases there is intentional duplication. Each restatement is based on different supporting information contained in the various chapters.

In this list, recommendations are not assigned priorities. They are arranged according to their appearance in each chapter. Agents and means of implementation are not stated specifically. This results from the fact that recommendations, regardless of how much support they have, remain opinions.

In solving the problems of dust fires and explosions in grain handling facilities, many alternatives are available. If applied, many could correct or at least alleviate the present situation. Those solutions which the Task Force proposes in this report are based on an assessment of current conditions and practices. In light of historical experience, these particular recommendations have the best chance of achieving the desired results in the shortest period of time and at the lowest possible cost.

In order to affect a problem, a solution must be implemented. To a large extent, this simple *sine qua non* explains why the problems of grain dust fires and explosions exist today. The United States has possessed the necessary knowledge and many of the prevention techniques for at least 60 years. It is obvious that they have not been adequately implemented. Otherwise, these problems would not exist.

The present U.S. grain handling system is significantly different than in the past. The changes which have occurred have added to the magnitude of the current problem. Grain dust fires and explosions now must be viewed as systemic problems in the handling system. Because they result from present conditions and practices, they are an inherent part of the operations and policies of the system. This does not mean that they will not respond to treatment.

The Task Force recognizes that implementation of all of these recommendations will take time. Applying only a part of these recommendations can significantly reduce the number of fires and explosions in grain handling facilities. If complete elimination of these problems is the intended goal, then partial implementation must result in a partial solution. In the short run this may be the best that can be achieved.

With these considerations in mind, one particular recommendation must be stressed—the removal of grain dust from handling facilities and the prohibition of its reintroduction into the handling stream. Application of this single recommendation can be expected to significantly reduce the magnitude of the current problem. Cleaner elevators, fewer fires, and fewer dust explosions will result.

Chapters 3 through 7 contain the following recommendations:

Chapter 3

- Develop analytical capability to describe and predict fire and explosion experience.
- Develop and use a system for technology and information transfer.
- Prohibit welding, cutting, and other hot work entirely within grain handling facilities during operation.
- Apply specific prevention measures to elevator legs.
- Develop and implement standardized design and construction guidelines for all new grain handling facilities. These should include requirements for isolating hazardous processes and areas, dissipating explosion effects through relief venting, and containing fire/explosion phenomena.
- Apply specific handling techniques which address the presence of large amounts of corn and its substantial artificial drying requirements.
- Monitor handling and processing equipment for a designated time period after shutdown.

- Determine why particular days of the week and certain periods of the month have higher incident rates than others.

- Study and determine exactly those factors which cause and contribute to variations in explosion experience.

- Establish a reporting system for fires and explosions in grain handling facilities which generates an accurate data base.

Chapter 4

- Perform remedial housekeeping and maintenance functions during daily downtime as part of a comprehensive maintenance and housekeeping program. If sufficient downtime is unavailable, elevators must designate some daily period for performing these functions.

- Develop and apply specific techniques suited to the handling of corn that will reduce breakage and dust generation and dispersal. Consider increased application of techniques, such as containerized shipments, choke feeding, deeper layers of grain on conveyor belts, and others as feasible.

- Develop and implement improved, more comprehensive levels of preventive and/or operational maintenance programming. Provide sufficient personnel for each operating shift to permit prompt performance of required maintenance work.

- Install emergency alarm systems.

- Relocate weight control rooms, as well as inspection laboratories, offices, locker rooms, dining areas, and maintenance shops away from the facility, and if possible, at a distance equal to the facility's highest point.

- Develop and implement standardized safety operations plans, and contingency plans (with emphasis on those items listed in appendix H).

- Standardize throughout the grain industry safety programs, safety techniques, and levels of safety practice, as far as possible.

- Implement improved safety measures and practices as developed through safety meetings and other means.

- Provide employees with improved safety and hazard recognition training and couple such training with more extensive and standardized safety programming and implementation.

- Provide periodic employee breaks in order to minimize fatigue and boredom and thus reduce the incidence of human error.

- Develop and implement more comprehensive levels of housekeeping programs. Provide sufficient personnel for each operating shift to permit prompt performance of required housekeeping work.

- Study methods for more equitable and more efficient distribution of grain within the handling system in order to balance the supply of services with demand.

- Conduct regular safety meetings and encourage all facility personnel and contractors to participate in developing, implementing, and monitoring safety programs.

- Establish standards for retrofitting and/or renovating grain handling facilities.

- Develop and implement improved and more comprehensive dust control programs which encompass mechanical collection, housekeeping, and other control measures.

- Determine the effectiveness of dust control programs by gauging dust accumulation in grain handling facilities over a period of time.

- Develop standards for design, manufacture, installation, operation, and modification of dust control systems and their component parts.

- Develop and implement increased levels of monitoring for design, manufacture, installation, operation, and modification of dust control systems and their component parts.

- Require grain handling facilities to collect dust from all dust-producing equipment or dusty locations within their facilities.

- Prohibit the reintroduction and recirculation of collected grain dust in grain handling facilities.

- Study and determine possible incentives, including tax relief, direct subsidy, and low interest loans, which could be used to promote increased levels of dust control in grain handling facilities.

- Develop requirements for dust collection systems that specifically address the unique characteristics of corn and the large volumes of corn handled.

- Require all dust storage to be located outside of and a safe distance from the grain handling facility.

- Study and determine existing and additional uses for grain dust, including the feasibility and the impact of these uses.

- Require each grain handling facility to develop and to implement a dust control program which would include mechanical dust collection, housekeeping, and other control measures. These

dust control programs should have a comprehensive maintenance program with a routinized system of repair, maintenance, inspection, renovation, etc.

Chapter 5

- Establish a responsible agency to coordinate the investigation of explosions in grain handling facilities.
- Require that all explosions and major fires in grain handling facilities be investigated and the results reported for analysis.
- Establish an interagency team of officials with specific expertise to make immediate investigations of all explosions and major fires in grain handling facilities. This team should provide both guidance and direction to facility operators and agencies responsible for enforcement of safety requirements.
- Develop and make available training in the techniques of explosion investigation as well as uniform guidelines and procedures for investigating explosions in grain handling facilities. These guidelines should set the minimum scope for investigations.
- Develop and establish better coordination among industry, government, and professional organizations in the development of consensus standards for grain handling facilities.
- Study and determine the effectiveness of such industry consensus standards in preventing dust fires and explosions as well as other hazards in grain handling facilities.
- Adopt appropriate industry consensus standards and uniformly enforce these as Federal, State, or local regulations.
- Develop and implement formal emergency preparedness plans for each grain handling facility in direct coordination and with the agreement of appropriate local authorities.
- Train all personnel employed in grain handling facilities for appropriate response procedures as outlined in facility emergency preparedness plans.

Chapter 6

- Remove dust from the grain stream in handling facilities.
- Prohibit reintroduction of collected dust in grain handling facilities.
- Apply other important techniques.
 - Implement improved housekeeping programs;

- Implement better maintenance programs;
- Increase safety training as well as more safety and hazard recognition training;
- Reduce available ignition sources;
- Design and operate new facilities with the explosion phenomena and its results as major design factors.

- Designate to a single government agency the responsibility for monitoring and enforcing the implementation of explosion prevention measures. Make this designation only if the results of voluntary compliance prove inadequate.

- Establish a NIC geared to the problems of grain dust fires and explosions.

- Develop and use, in conjunction with the grain industry and others involved in handling grain, appropriate mechanisms for disseminating pertinent information and techniques relating to safety in grain handling facilities.

- Establish a permanent interagency council for evaluating the present and future needs of the grain handling and processing industries as they concern grain dust fires and explosions and other operational problems. The interagency council should provide necessary guidance and direction to the Government and to the grain handling and processing industries.

Chapter 7

- Require the development and implementation of comprehensive operations plans which include programs for maintenance, housekeeping, safety, and security.
- Monitor the U.S. handling system in order to identify possible trends affecting fire and explosion hazards.
- Collect and remove all grain dust, particularly corn dust, from handling facilities.
- Prohibit reintroduction of dust into the grain stream.
- Research alternative and/or more equitable export grain distribution and handling systems.
- Research existing design and construction criteria and operation of the grain handling system for the purpose of minimizing handling system dysfunction caused by fires and explosions.
- Consider the application of those safety features and techniques used by the Australians in the construction of new U.S. grain handling facilities.
- Consider the application of those safety techniques which have proved successful in Australia

for the retrofitting or renovating of existing U.S. grain handling facilities.

- Perform additional research on the effects of R.H. as it is related to fire/explosion phenomena. This research should include:

- (1) Expanded statistical analysis of explosion incidents with regard to R.H.

- (2) Laboratory determination of the major processes and variables involved in grain and grain dust water sorption phenomena.

- (3) Laboratory and *in situ* quantification of this process.

- (4) *In situ* determination of the rate at which the sorption phenomenon proceeds and the resulting effects on ignition energy requirements.

Chapter 2

BACKGROUND

Since the phenomenon of grain dust explosions has been of concern for many years, numerous remedies have been proposed to make grain handling and processing safer. The same general recommendations resurface whenever there is an extremely destructive explosion or series of explosions.

Advances in technology occasionally result in new approaches to the problem, but for the most part remedies proposed even 60 years ago are remarkably similar to those proposed today. The following material, excerpted from *USDA Bulletin No. 681*, published by the GPO on May 18, 1918, demonstrates this point (ref. 1). This bulletin was completed in conjunction with USDA's "special war-emergency campaign for the prevention of dust explosions and fires."

Several definite causes for these (dust) explosions have been established, and effective preventive methods have been developed and tested.

As soon as possible after the occurrence of an explosion in a mill or elevator, the field engineers of the (USDA's) Bureau (of Chemistry) investigate the conditions under which the explosion originated and assist the company to devise and install some means for preventing any more such explosions.

The final conclusions reached after studying grain dust explosions in an experimental attrition mill, together with the other results obtained by Government investigators, may be summarized as follows:

- 1. Every effort should be made to collect and remove the dust from the grinding mill and surrounding atmosphere.*

- 2. In some cases it may be advantageous to use inert gases to decrease the oxygen content and thus prevent the formation of an explosive mixture of air and dust.*

- 3. Every possible source of heat should be eliminated where there is any danger of having a dust-laden atmosphere.*

- 4. Every precaution should be taken to eliminate sparks due to static electricity.*

- 5. Greater use should be made of sheet iron (in lieu of wood for equipment and structural members) on account of the very great danger from smoldering lumps of grain (as ignition sources).*

- 6. Revolving (explosion) dampers, as installed here and elsewhere, appear to be of some value as preventive measures for the propagation of explosions.*

- 7. The principle of the automatic relief valve should receive more attention as a possible remedy to apply for the partial prevention of the propagation of the flame.*

In addition, this publication offers the following recommendations for future (scientific) investigations:

- I. Laboratory experiments (should be conducted) to determine the limits of inflammability as affected by . . .*

- 1. Density of the dust cloud.*

- 2. Fineness of the dust particles.*

- 3. Chemical composition of the dust.*

- 4. Moisture content.*

- 5. Inert gases.*

- 6. Atmospheric humidity.*

- 7. Minimum temperature and amount of heat required for ignition.*

- 8. Sparks from metallic substances.*

- 9. Static electricity (not merely the voltage, but current measurements as well).*

- II. Field experiments (should be conducted) on various types of machines handling dusty materials:*

- 1. Tests to prove that dust mixtures outside the limits of inflammability, as already determined, with respect to moisture content, inert gases, or atmospheric humidity, cannot be ignited under the most severe conditions of ignition, such as those produced by an electric arc.*

- 2. Tests of various devices designed to prevent the propagation of explosions.*

The number of grain elevator fires and explosions has not been reduced or eliminated. Because this problem has continued, past solutions have been inadequate. Whether this inadequacy is inherent in the solutions themselves or in their application is uncertain.

The Task Force recommendations are based on analyses of various aspects of the present U.S. grain handling system and its component parts. They are geared to present handling techniques and situations believed to be common in the handling system. Because historical experience was misstated, misinterpreted, or incomplete, justification for present recommendations was developed primarily from analyses of present conditions.

During the 1970's major changes occurred not only in the grain handling and marketing system, but also in the enforcement of occupational safety and health, and in the monitoring and enforcement of environmental quality. These changes and their ramifications may have created two separate, linear sets of experience, past and present. Of course there are some elements common to the topic of grain handling regardless of the period involved. Conclusions and recommendations developed from an indiscriminate mix of data may be inherently biased toward a historical situation which no longer exists.

Based on the above considerations, the sections following in this chapter set the stage for current analyses of the grain dust fire and explosion problem. More specific analyses of dust explosion incidents are found under section 3.1.

2.1. GENERAL HISTORY

Although dust explosions have been reported for almost two centuries, an understanding of their true character was slow in developing. In particular, great difficulty was experienced in accepting that an explosion could be caused by dust alone, and that the presence of a flammable gas to support the explosion was unnecessary. An account of a flour dust explosion in Turin, Italy, in 1785, was published shortly after the incident. It was postulated that ignition first occurred in flammable gas given off by the disturbed dust, although it was realized that the dust itself contributed to the subsequent explosion. Not until 100 years later was it accepted that ignition of the dust could initiate and propagate an explosion (ref. 2).

The explosibility of coal dust in mines had been researched, demonstrated, and accepted much earlier than that of grain dust. In 1907, 1,148 mi-

ners were killed in the United States; 588 were killed in just two explosions. The U.S. Bureau of Mines was established as a result in 1908.

Eighteen persons were killed in a flour mill explosion in Minneapolis in 1878, and 60 more deaths were recorded in agricultural dust explosions by 1913. It was not until 33 persons were killed in 1913 at a Buffalo, New York, feed mill that nationwide concern was felt outside of the industry. As a result, USDA's Bureau of Chemistry, among others, initiated a study of the explosibility of agricultural dusts. Before this study was completed a catastrophic explosion occurred at a starch factory in Cedar Rapids, Iowa; this incident caused 43 deaths and 33 injuries. Five years later another starch plant explosion killed 42 persons and injured 22 others (ref. 4).

From 1925 through 1956 there was a total of 282 dust explosions with an average yearly estimate of incidents in grain elevators, flour mills, and feed and cereal mills of about 9 incidents per year (ref. 4). In comparison, Task Force statistics derived from a total of 195 incidents indicate that during the period 1958 through 1974 the average number of grain dust explosion incidents increased to more than 11 per year (See section 3.1.).

Early in 1976 two disasters killed 14 and injured 20. There began a sequence of 42 explosions which peaked in the 7 days from December 21-28, 1977. Of the 87 deaths and 164 injuries resulting from these explosions, 5 incidents during one week in December, caused 59 deaths and 49 injuries. During the period 1975 through 1978 current records list 55 explosion incidents. This is an average of nearly 14 incidents per year.

2.2. RECENT HISTORICAL PERSPECTIVE

The following section shows in general terms, the historical magnitude of grain dust explosions and fires and of the resulting deaths and injuries. The Task Force compiled material for the period 1958 through 1978 by consolidating data from several sources (refs. 4, 5, 6, 7, 8, 9). Data on many of the latter incidents was developed through Task Force field activities. This material is presented in table 1 and graphically as histograms in figure 1. A complete list of known explosion incidents is also included in appendix A. Efforts continue to verify all of the incidents listed and to identify those not previously recorded.

Source materials used in compiling the present listing were not very accurate because of the lack

Table 1.—Explosions, deaths, injuries, and fires in grain handling facilities in last 21 years

Year	Number of explosions in U.S.	Number of deaths	Number of injuries	Estimated number of fires in elevators* (NFPA)
1958	10	2	27	3200
1959	10	3	18	2200
1960	12	4	18	2300
1961	10	0	17	2100
1962	9	3	51	2300
1963	14	3	30	2200
1964	8	3	22	2000
1965	9	2	5	1900
1966	14	2	22	2000
1967	17	1	14	3000
1968	16	12	38	5300
1969	6	4	13	4700
1970	10	1	14	3000
1971	10	4	14	3100
1972	8	7	23	2400
1973	8	2	10	1800
1974	15	13	37	2200
1975	9	4	19	2200
1976	22	22	82	-
1977	21	65	84	-
1978	12	7	47	-
Totals	250	164	605	

*Estimated number of fires in elevators unavailable after 1975

of an extensive reporting system. Other problem areas can be identified which complicate historical research in grain dust fires and explosions. Specifically, these are as follows:

1. Inconsistent fire and explosion reporting;
2. Variability in the kinds of information reported following an incident;
3. Unavailability of records because of elapsed time since the incident or because of legal or practical constraints prohibiting release; and
4. Inaccuracy in reporting.

These constraints, either singly or in combination, prohibit assurances of complete accuracy in appendix A, table 1, and in figure 1. The trends which are shown are valid, especially if these known incidents are considered as a generally representative sample of all incidents during this period.

2.2.1. Explosion Histogram

The first histogram in figure 1 shows the yearly number of recorded explosion incidents from 1958 through 1978.

There are approximately 15,000 grain storage and handling facilities in the United States. This figure includes grain elevators, feed mills, flour mills, and other grain processing plants. Many of these facilities store, handle, and process grain,

and can be considered multiuse facilities. The distinction between the different types of plants is often unclear in published records. This point is clarified in appendix J.

From 1958 through 1978 there were 250 dust explosions in grain handling facilities. During this 21-year period, dust explosions averaged almost 12 per year, ranging from 6 in 1969 to 22 in 1976. The number of incidents in 1976 and in 1977 far exceeded the number of explosions in any previous sample year. In 1978 there were 12 explosions. Additional breakdowns are given in table 2.

Table 2.—Average yearly explosion incidents

Period			Average yearly incidents
1.	1958-67	(1st 10 yrs.)	11.3
2.	1968-77	(2nd 10 yrs.)	12.5
3.	1958-60*	(3 yrs.)	10.6
4.	1961-65	(5 yrs.)	10.0
5.	1966-70	(5 yrs.)	12.6
6.	1971-75	(5 yrs.)	10.0
7.	1976-78	(3 yrs.)	18.3

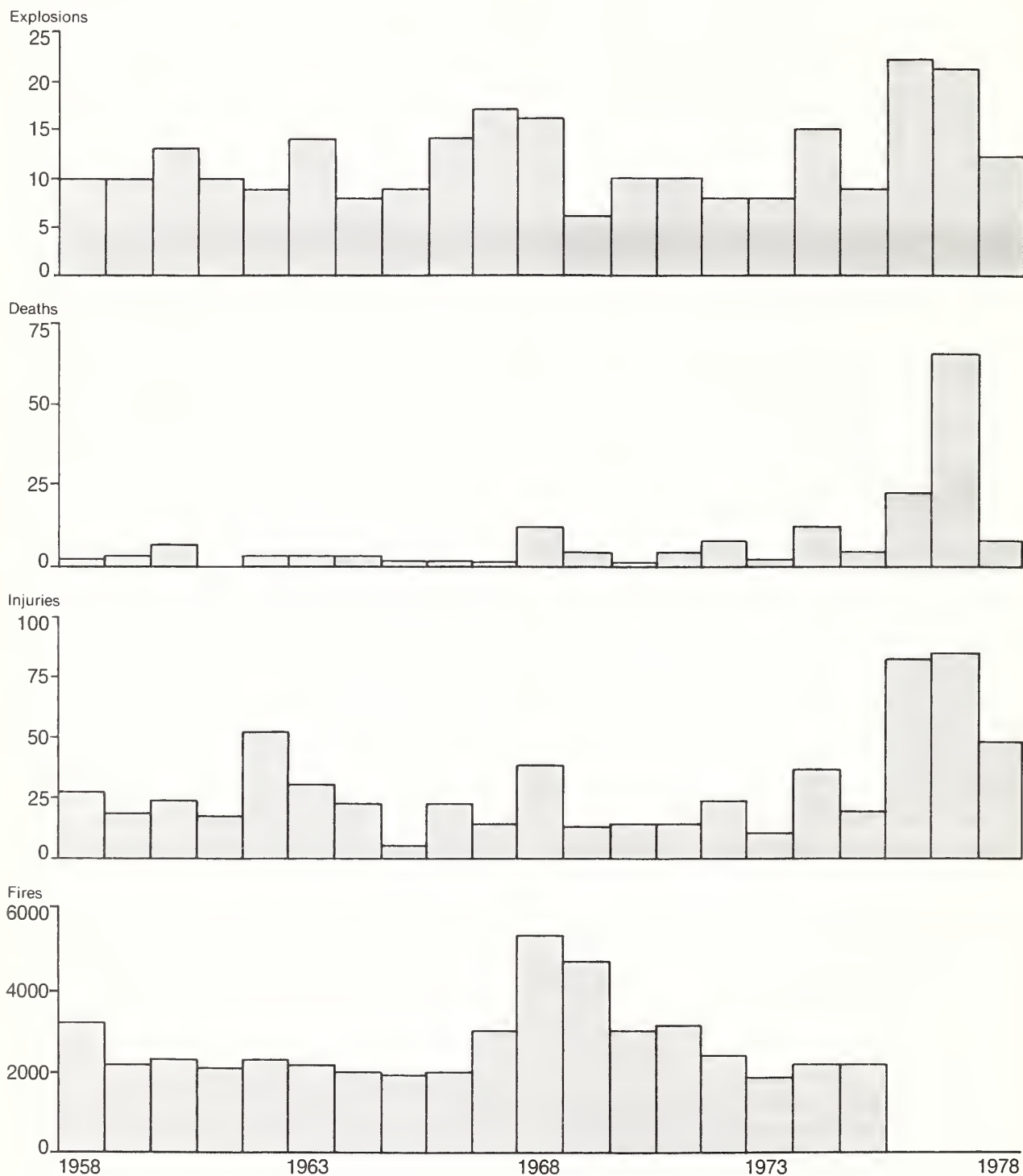
With the exception of periods 5 and 7, the yearly average of explosion incidents has remained relatively constant. These two periods, 1966 through 1970 and 1976 through 1978, seem to be anomalous situations with relatively high, sustained incident levels. At the present time, this has not been explained satisfactorily but the situation may be affected by inconsistent reporting.

Looking at this histogram as a whole, two additional characteristics bear mentioning, although they too are unexplained. Yearly explosions range from a high of 22 incidents in 1976 to a low of 6 for 1969. The low years are low only when compared to high incident years. Actually, there are only high years and years with relatively fewer occurrences. During the last 21 years there were no low years. This indicates that dust explosions may be systemic, i.e., they seem to be an inherent part of the U.S. grain handling system with only "normal" and "high" yearly incident levels.

This concept of grain dust explosions as a systemic problem is central to the solutions recommended by K. N. Palmer, Fire Research Station, Borehamwood, United Kingdom. In Palmer's view, dust ignition and explosion can be minimized in grain elevators but cannot be eliminated entirely. He believes that in addition to appropriate facility design criteria, any solution to the problem must focus on reducing the effects of ignition and explosion. In grain elevators, this can be achieved through the use of relief venting, inerting, automatic suppression, or isolation of hazardous areas (ref. 3).

Figure 1

Explosions, Deaths, Injuries, and Fires in Grain Handling Facilities in the Last 21 Years



Fire data is estimated and unavailable after 1975.

Figure 1 Explosions, Deaths, Injuries, and Fires in Grain Handling Facilities in the Last 21 Years

While this particular approach has proved useful in the United Kingdom, it may have limited applicability in the United States. The U.S. grain handling system encompasses an estimated 15,000 facilities. Many are old and were built according to guidelines which have since been improved, at least in part. The task of retrofitting these facilities to comply with current guidelines and standards may be functionally as well as economically impossible. Palmer's approach might be applied to the construction of new facilities, but this in effect addresses only a part of the problem.

The second characteristic of the explosion histogram in figure 1 concerns the fluctuation between "high" incident years and "normal" incident years. This fluctuation appears to be slightly cyclical and might, in part, follow relative fluctuations in the demands placed upon the system. Inconsistencies in reporting are another possible explanation.

2.2.2. Histograms of Injuries and Fatalities

During the 21-year period, 1958 through 1978, deaths averaged less than one per incident. Injuries per explosion were about 4.7 times more common than deaths with an average of 2.4 per incident. While the yearly number of injuries has fluctuated widely the number of deaths per year has remained relatively constant. In 1974, both injuries and deaths showed large increases over previous levels. Following reduced levels in 1975, both showed huge gains in 1976 and 1977 with 1977 the higher of the two. Although deaths dropped back to previous levels in 1978, the number of injuries did not drop as drastically. Injury levels remained below the 1976-7 levels, but were still higher than any year since 1962.

2.2.3. Histogram of Estimated Fire Experience

The fourth histogram in figure 1 was developed from data provided by NFPA (ref. 6). The data reflects only the years 1958 through 1975. NFPA changed its reporting procedures after 1975.

As the histogram shows, there was a large increase in the estimated number of fire incidents in 1968 and 1969. The number of fires in the grain handling industry during the entire period averaged about 2,700 incidents per year. With over 15,000 grain handling facilities in the United States, the result is an estimated incident ratio of roughly 18 fires for every 100 facilities now in operation.

Export fire data available for part of 1978 (See section 3.4.) indicates that these estimates may be

understated by a factor of 3 or 4. Even assuming only partial comparability between the export segment of the handling system and the other segments of the system, previous estimates may have been understated by at least a factor of 2.

2.3. USDA INVOLVEMENT

On January 25, 1978, Secretary of Agriculture, Bob Bergland, appointed John V. Graziano as a Special Assistant to the Administrator of FGIS. Mr. Graziano was directed to head the Department's activities regarding grain elevator fires and explosions. This was in response to the two December export grain elevator explosions which not only killed 54, injured 32, and destroyed over \$50 million in property, but threatened to disrupt U.S. grain exports (thus adversely affecting the already large balance of payments deficit). Thirteen FGIS employees were killed and four injured in these two explosions.

FGIS is a relatively new addition to USDA, established on November 20, 1976, when the Grain Standards Act (7 U.S.C. 71, *et seq.*) was amended by the 94th Congress. Although considerably expanded, the present FGIS is the successor agency to the Grain Division of AMS. FGIS has been charged with promoting and protecting the interstate and foreign commerce of grain. Primarily, this is achieved through the application of an officially sanctioned grain grading system in conjunction with a system of official weighing and supervision of weighing.

The Grain Standards Act and the regulations under this Act require that most grain exports be officially inspected and weighed. At export locations, this "regulatory service" is performed either by FGIS employees or by licensees who are State employees and are actually stationed in export grain handling facilities. Thus, FGIS personnel have been continuously present in export facilities since the end of 1976.

At interior locations services available under the Grain Standards Act are generally provided by licensees. These licensees operate under the authority of the Act and are directed through a system of FGIS regional and field offices. Licensees may be employed either by states or by private agencies.

The T&W of USDA's AMS also has responsibilities in grain elevators. Operating under the authority of the U.S. Warehouse Act, as amended (7 U.S.C. 268), T&W licenses individuals to inspect and weigh grain in grain handling facilities. T&W programs and services are voluntary and include the licensing of facilities and persons, the

examination of facilities for storage suitability, and the measuring of storage inventories to determine if they meet receipted (and unreceipted) obligations for the delivery of grain. T&W employees are not stationed in facilities on a continual basis although licensees often are.

Although FGIS and T&W are the two agencies primarily concerned with handling grain, many other USDA agencies are involved in all phases of the production, marketing, processing and use of grain and grain products. Much of this extensive involvement has prevailed for many years. Thus, USDA's present involvement in the problem of grain dust fires and explosions in handling facilities is a natural result of a long-standing relationship defined by a general policy of assistance and service to agriculture.

The present Task Force mandate is not without historical precedent for its mission closely parallels that of USDA's former Bureau of Chemistry. Sixty years ago USDA provided assistance in assessing and recommending solutions to the problems of grain dust explosions and fires in handling facilities (ref. 1). The high toll of recent explosions in terms of injuries, deaths, both USDA and facility employees, property loss, and reduced export capacity underscores the urgent need for increased efforts in this area.

2.3.1. Formation of USDA Special Task Force

In order to implement the Secretary's directive, Mr. Graziano established a Special Task Force on Grain Elevator Safety and Explosions. The Secretary's charges to this Task Force were as follows:

1. Determine the causes of grain elevator explosions (chapter 3).
2. Identify major safety hazards in grain elevators (chapters 3, 4, and 6).
3. Identify potential hazards in grain elevators which may not be documented (chapter 7).
4. Identify safety precautions appropriate to grain elevators (chapters 1 and 7).
5. Analyze the adequacy of current investigations, enforcement practices, legislation, and regulations (chapter 5).
6. Determine the number and exact causes of deaths and injuries resulting from dust and methane explosions (chapter 3).
7. Establish safety guidelines for USDA employees working in grain handling facilities (chapter 2).
8. Recommend criteria for a safety program and necessary administrative, organizational, or legislative changes (chapter 2).

9. Coordinate USDA efforts with those of industry and other Federal, State, and local government agencies (chapter 2).

The Task Force was instructed to address a wide range of topics within the general problem area of grain dust fires and explosions. In the past research with its resulting recommendations was confined to areas of limited scope. In the confusion following the December 1977 disasters no single entity emerged in either industry or government which seemed to have the authority and expertise necessary to attack the problem in its entirety. Safety experts were unfamiliar with grain dust explosions; explosion experts were unfamiliar with grain or grain handling techniques; and specialists in environmental quality were unfamiliar with grain marketing techniques or safety. Although expertise was available, it was neither coordinated nor focused. It was this lack of coordination and direction which USDA identified and attempted to remedy through the creation and operation of the Task Force.

The Secretary later established the new position of Special Coordinator for Grain Elevator Safety and Security to succeed the special Task Force. The Secretary decided to continue this activity to ensure the continuation of the benefits resulting from the Task Force operation.

2.4. SUMMARY OF TASK FORCE ACTIVITIES AND METHODOLOGY

In order to achieve the goals set by the Secretary, the Task Force first examined resources which could be mobilized and applied to solve the problem of grain dust fires and explosions. A review of existing literature disclosed that the following general activities could provide the most productive results.

1. Compiling existing data in a usable form;
2. Developing and implementing immediate government/industry activity to allow safe, uninterrupted handling and merchandising of grain and grain products;
3. Supplementing existing data regarding grain elevator conditions, operating practices, and safety and health enforcement;
4. Facilitating the development of a viable long term research strategy; and
5. Analysis of data.

Within these general areas, the Task Force conducted those specific activities listed in the remainder of this chapter.

2.4.1. Questionnaires and Studies

- **Explosion Incidents:** In order to carry out an indepth survey of the explosion incidents depicted in figure 1, a questionnaire was prepared (appendix B). Interest areas based on probable fire/explosion causes and contributing factors were identified and appropriate questions developed. Questions were based on the well-documented fact that three ingredients are required for a dust fire or explosion—a sufficient quantity of appropriate *dust*, *oxygen*, and an *ignition source*. Most questions were directed toward identifying elevator operating conditions, procedures, and practices which could augment any of the individual parts of this fire/explosion triangle. Other questions addressed factors which could contribute to a grain elevator fire/explosion incident or affect the severity of such an incident.

The Task Force compiled extensive information on 15 explosion incidents. This data is summarized in appendix C. Because of varying record retention limits for Federal, State, and local authorities, these 15 incidents were selected from those which occurred since 1975. This selection ensured that some records would be available. A limited amount of pertinent information was also available for other samples of varying sizes. This material is presented under chapter 3.

- **Export Conditions:** Questionnaires were prepared, addressing conditions in export terminals (appendix D).

Fifty-five export grain elevators were surveyed using these forms. In part, this sample was selected because FGIS personnel are stationed at these export locations on a continual basis. Another factor was that the export segment of the U.S. handling system is, because of the limited number of facilities, a complete sample of a manageable size. The purposes of the survey were to determine current conditions in these facilities and provide a basis for comparison with facilities where major fires or explosions have occurred. Most of the survey questionnaires were completed during personal interviews with the elevator managers of each facility. Findings are presented in section 4.1. and summarized in appendix E.

- **Dust Handling:** As part of the survey of the 55 grain export facilities, a portion of the questions was designed to determine the extent of dust recirculation and to provide comprehensive background on applied technology of dust collection systems. Discrepancies in the type and amounts of data gathered during this part of the survey resulted in the design and use of a second ques-

tionnaire and survey (appendix F). Both questionnaires served the same purpose.

Copies of the second dust collection questionnaires were sent through the FGIS Operations Staff to Regional Directors and Field Office Supervisors. Generally these were completed by FGIS field office personnel. In some instances questionnaires were completed by export facility employees with access to the required information. The results are presented under section 4.5. and summarized in appendix G.

- **Federal, State, and Local Authorities:** The Task Force surveyed Federal, State, and local authorities responsible for the enforcement of various building, safety, health, environmental quality, and emergency operation codes in the geographic area of each facility surveyed. After determining the types of compliance activity implemented in each of the regulatory areas, or the kind of collateral service provided, each agency's records were examined to determine the level of enforcement activity regarding grain handling facilities, the antecedents and adequacy of those laws and regulations being enforced, and the level of success in obtaining compliance with these existing laws and regulations. Findings are presented under chapter 5.

2.4.2. Other Studies

The Task Force conducted several additional studies as follows:

- **Analysis of 1978 Export Fire and Other Hazard Condition Reports:** The Task Force instituted procedures for reporting hazard conditions occurring in grain handling facilities. Although in no way limited to the export segment of the handling system, FGIS employees stationed at export facilities used the Hazard Report System almost exclusively. A description of the system and summaries of the reports received are contained in section 3.4. Reported export facility fire experience is also compared with previous NFPA estimates and presented in that section.

- **U.S. - Foreign Grain Handling:** Initial reports submitted by the attaches of USDA's FAS indicated that there are several foreign countries which have had no recent elevator fires or explosions. It became important to gain firsthand knowledge concerning foreign grain handling systems in order to identify those factors which could be responsible for the apparent lack of foreign fire/explosion incidents. USDA investigators spent approximately 2 weeks on a factfinding tour of Australian grain handling facilities. Other

foreign grain handling systems were not visited because of operational constraints. However, a delegation from South Africa presented material at the International Symposium on Grain Elevator Explosions, held in July 1978. Information gathered in this way is presented in section 6.1.

- **Relative Humidity:** Confusion and argument exists about the possible role of atmospheric R. H. in grain dust explosion phenomena. In order to clarify the situation and assist FGIS in developing hazardous R. H. parameters, the Task Force conducted a pilot study of R. H. and its relation to grain dust explosion incidents.

Twenty-four explosion incidents were selected on the basis of available data. R. H. readings were obtained from the closest NOAA reporting stations. For the most part these readings covered a period of 8 days, the 7 previous days and the day of the incident, in approximately 3-hour intervals. This material is presented under section 7.4.

- **Static/Ambient Dust:** This study describes ambient dust concentrations which could result when static dust deposits of several different grains are dispersed into the air inside a grain handling facility. The study was intended to provide a possible means of quantifying the effectiveness of dust control systems and other housekeeping measures. This should assist those who must assess the buildup of dust deposits as a means of determining the attendant degree of hazard involved.

Primarily, the study consists of mathematical computations performed with maximum and minimum dust density figures. The derived tables show the weight of various dusts which would be required to cover an area of 100 ft². Charts then show the resulting dust concentrations if the various amounts of dust were evenly dispersed throughout a 1,000 ft³ (10 ft x 10 ft x 10 ft) volume of air. Findings and discussion are presented under section 7.1.

- **Export Grain Handling System:** This study statistically describes the grain export handling system. It shows how various grains have been apportioned throughout the system for the years 1975 through 1977 and how this might relate to the incidence of dust explosions in the export handling system. It is based on export inspections performed by FGIS and on other information available through USDA. This study is presented under section 7.2.

- **Limited FGIS Management-Use Studies:** The Task Force also conducted three studies of limited scope for FGIS, all of which focused on grain

exporting facilities. The first detailed the location of FGIS grain inspection laboratories on elevator grounds and the distances separating them from elevator headhouses. The second covered the location of grain elevator emergency exits from headhouses. The third queried FGIS field personnel and elevator managers regarding dust collection systems at elevators. Results of all of the above were intended for use as an immediate FGIS management tool and are not contained separately in this report. Some of the material has been combined with that of other studies.

2.4.3. Other Activities

- **International Symposium:** The International Symposium on Grain Elevator Explosions developed from a Task Force observation that although information about the problems of grain dust fires and explosions are available, it has not been generally disseminated to the grain industry and to others in the field. USDA sponsored a meeting of international experts through the NMAB of the NAS. Authorities from many countries and from many different fields of study met on July 11 and 12, 1978, in Washington, D.C. They presented the results of their research, assessed problem areas and deficiencies, and recommended alternative solutions to the problems of grain dust fires and explosions. The major points developed during the course of this symposium as well as conclusions and recommendations of the Task Force are presented in chapter 6.

- **Development of Guidelines:** The development of guidelines for safety operations plans proceeded from the observation that unsafe practices and conditions could be found in almost all grain elevators. These policy and/or operational deficiencies, based on a consensus of informed opinion, contribute to a greater likelihood of fires and explosions. In order to promote increased implementation of standardized, safety-conscious operating practices and policies, the Task Force prepared a checklist entitled "Guidelines for Safety Operations Plans" (appendix H). The material in this checklist closely parallels that commonly found in corporate safety manuals. It is divided into five sections.

1. Safety Program—Policies, Procedures, and Instructions
2. Housekeeping
3. Maintenance of Major Elevator Equipment
4. Security
5. Emergency Preparedness.

The checklist covers those activities where an increased effort on the part of facility managers and employees could result in substantially safer working environments. Mandatory elevator implementation and review of these items are currently under consideration by USDA for possible inclusion in proposed FGIS regulations.

- Task Force Inputs to the FGIS Safety Program: The Secretary's instructions required that the Task Force provide continual input to the FGIS safety program. Primarily, this took three forms:

1. Developing guidelines and instructions to enable FGIS field employees to recognize hazardous conditions and practices in grain handling facilities;

2. Formulating viable procedures and policies to guide personnel in their responses to recognized hazardous conditions; and

3. Assisting FGIS in the development and organization of an effective safety program.

Task Force activities under numbers 2 and 3 generally consisted of evaluation of existing or proposed FGIS program with analysis being submitted directly to the appropriate FGIS officials. Final action is still pending in many cases so a detailed listing and analysis of this type of material would be premature. Several Task Force recommendations do incorporate some of this material.

The combination of activities under number 1, developing guidelines and instructions relating to hazard recognition, is one of the recurring themes of this report. Recognizing and correcting the hazardous conditions or practices thought to con-

tribute to and cause grain elevator explosions cannot be limited only to FGIS. Remedies must be applied throughout the grain handling system by all involved.

- Liaison with Industry, Government Agencies, and Researchers: In addition to the International Symposium and the other activities addressed in preceding sections of this chapter, the Task Force stimulated an increase in communications among the grain industry, ancillary service industries such as manufacturers of grain handling and dust collection equipment, academic researchers, and other Federal, State, and local authorities. The free exchange of ideas, techniques, and information plays an integral part in identifying viable solutions to problems existing in the grain handling system.

Within the present complex of industry-government interaction, the problem of grain elevator safety involves substantial input from a bewildering number of actors in the public and private sectors. Currently, there is no widely accepted method of soliciting the necessary information from all sources, including academic researchers. Lacking these basic inputs, a clearly mandated course of corrective action, and the general dissemination of safety information to all of the individuals involved in grain handling remains a tenuous possibility.

The degree of cooperation encountered by the Task Force, although weak in some areas, was a definite step toward a functioning community of interest in grain elevator safety. This report would have been an impossibility without the significant cooperation of industry, academia, and many government agencies.

Chapter 3

HISTORICAL DATA ANALYSIS

As required in the Secretary's original instructions, the Task Force analyzed explosion data to determine causes of explosions, the circumstances surrounding deaths and injuries, and the other relationships involved in grain dust explosion phenomena. Appendix A represents the most complete list of dust explosion incidents now available; it provides the basis for all analyses in this chapter.

While verifying the incidents on this list, the Task Force obtained additional information, although this information was not available for all incidents. The varying sample sizes used in different analyses reflect this fact.

Chapter 3 consists of six parts. The first contains a general analysis of 250 recorded explosion incidents. The second contains detailed analyses of selected incidents for which more information was available. The third contains additional analyses of samples of varying sizes, including a comparison of several factors thought to cause or contribute to an increased likelihood of explosion. State rankings by numbers of explosions are used almost exclusively. The fourth part contains material regarding hazard conditions reported at export grain elevators. This section completes the analysis found in this chapter. The remaining two sections contain Task Force conclusions and recommendations.

3.1. ANALYSIS OF RECENT DUST EXPLOSIONS

The Task Force analyzed available information for fires and explosions in grain handling facilities, deaths and injuries resulting from these incidents, recorded ignition sources, and the purported location of primary explosions within facilities. Additional analyses were made of the circumstances surrounding these explosions by comparing them on the basis of time of the day, the day of the week, the day of the month, the month of the year, established commodity delivery months, and normal harvest periods.

3.1.1. Deaths and Injuries

A total of 250 recorded explosions during the 21-year period from 1958 through 1978 caused 164 deaths and 605 injuries (table 1 and appendix A). The greatest number of persons killed and injured in a single recent explosion was 45 (36 people killed and 9 injured) in a grain elevator in Westwego, Louisiana, in 1977.

Not all grain dust explosions have resulted in deaths or injuries. During the 21-year period, deaths and injuries were recorded in 58 percent of the incidents. Only 21 percent of the incidents resulted in fatalities while 55 percent resulted in injuries. Of the 145 incidents where death and/or injury resulted, a total of 769 deaths and injuries were reported, an average of over 5 per incident.

Across the entire sample, there were nearly 3.7 times as many injuries as there were deaths. Deaths averaged nearly 8 per year while injuries averaged almost 29 per year for a total of about 37 injuries and deaths per year as a result of grain dust explosions in handling facilities. During the 21-year period, the average was less than one death per incident.

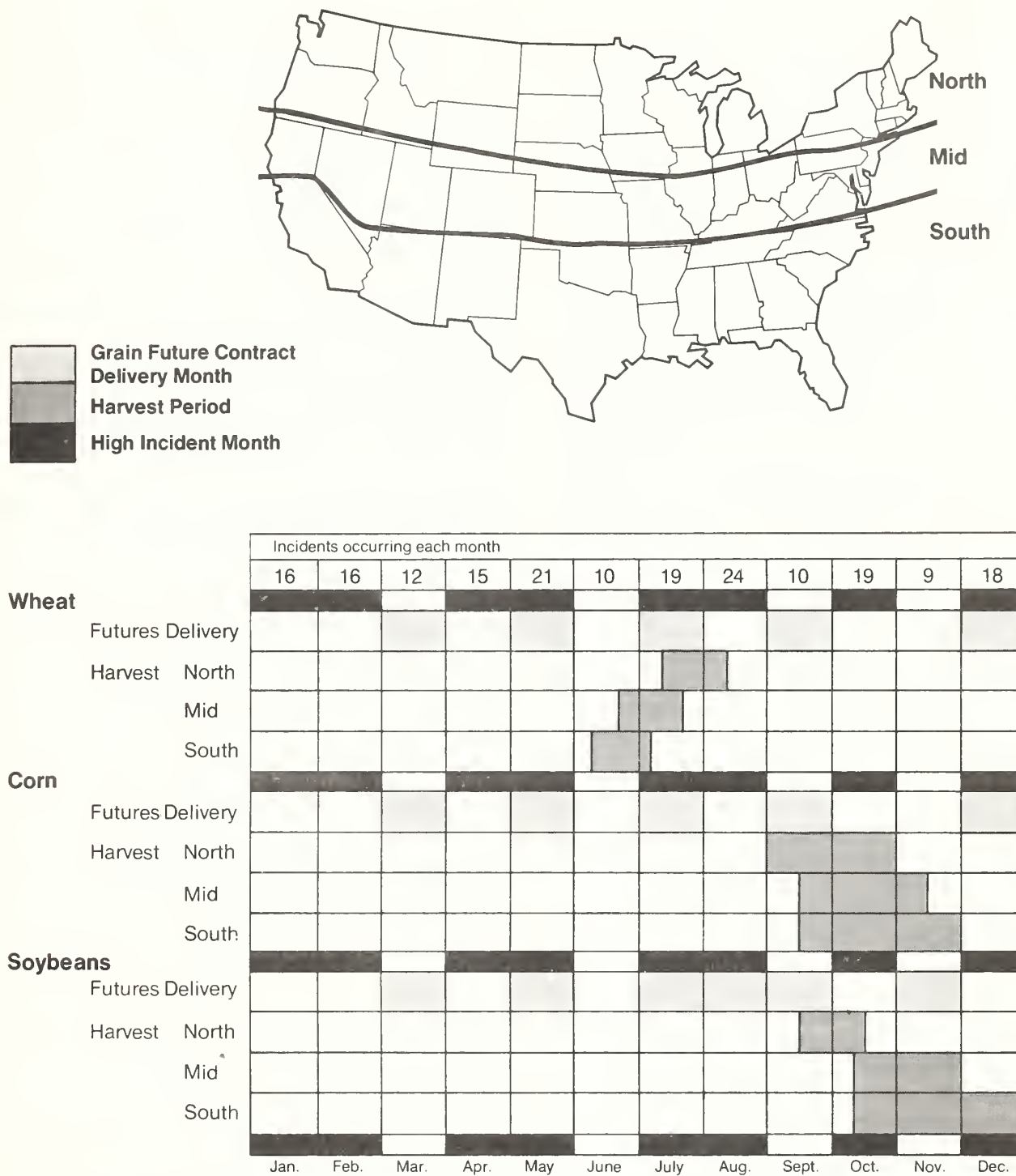
While the number of injuries has fluctuated widely from year to year, the number of deaths has remained more constant. In 1974, both injuries and deaths showed large increases over previous levels. 1975 reflected reduced levels but both categories showed large gains in 1976 and especially 1977. Although deaths returned to lower previous levels in 1978, the number of injuries did not make a similar decline. Injuries remained below the 1976 and 1977 levels, but were still higher than any previous year since 1962.

3.1.2. Explosions Per Month

Dates were available for 189 of the 250 explosions, 75 percent of all recorded explosions during the period. The belief that most explosions have occurred during the cold, dry months is not supported by the data. In fact, table 3 shows that the largest number of explosions has occurred dur-

Figure 2

Grain Harvesting, Future Delivery Months, and Explosion Incidents



Future delivery months, Chicago Board of Trade

Figure 2 Grain Harvesting, Future Delivery Months, and Explosion Incidents

**Table 3.—Explosion incidents per month, 1958 to 1978
(Sample size - 189)**

Month	No. of grain elevator & feed mill explosions	Percent of total dated explosions
August	24	12.70
May	21	11.11
July	19	10.05
October	19	10.05
December	18	9.52
January	16	8.47
February	16	8.47
April	15	7.94
March	12	6.35
September	10	5.29
June	10	5.29
November	9	4.76
Total	189	100%

ing August (12.70 percent) followed by May (11.11 percent). These two warm months are followed by October and July (10.05 percent each), December (9.52 percent), and January and February with 8.47 percent of the dated explosion incidents. Further analysis of monthly totals for a similar sample is contained in section 3.1.3.

3.1.3. Future Contract Delivery Months and Regional Harvest Periods

In this section, the monthly distribution of 189 explosion incidents is compared with future contract delivery months and regional harvest periods for three grains - wheat, corn, and soybeans. This material is shown by a graph in figure 2. Monthly distribution of incidents is also compared with the general activity schedule of country elevators.

During the sample period of 21 years, the distribution of incidents ranged from a high of 24 in August to a low of 9 in November. Within a single calendar year, figure 2 shows three groupings of 3 months each for the first 9 months (January through September). The 3-month groupings consist of two high incident months followed by a relatively low incident month. For the purposes of this particular section, a low incident month is defined as one with 14 incidents or less. The last 3 months of the year comprise a separate grouping of alternating high and low incident months.

Looking at this in a different way, the data shows one grouping of three high incident months - December, January, and February, two additional groupings of two high incident months - April-May and July-August, and one additional high incident month - October. Each group is separated from other high incident groups by low incident months.

While figure 2 shows little correlation among high incident months, future contract delivery months, or regional harvest periods, excepting

wheat and corn harvests during October, there is a great deal of correlation when monthly explosion incidents are compared with the general activity schedule of most country elevators.

July, a high incident month, is usually a period of great activity and low storage inventories as old crop grain is moved into the marketing system. August, another high incident month, generally finds inventories depleted as the last of old crop grain is moved out of the elevators in preparation for the new harvest. Many facilities spend part of the month of August cleaning the bins and preparing facilities for the harvest rush. Most present cleaning practices result in the dispersal of large amounts of dust into the air inside the facility.

During October, most facilities are in the midst of the corn and soybean harvest. This is a month of great activity and has a high incident rate.

The 3 high incident months - December, January, and February - can be the period during which high moisture grain brought in during harvest is dried. The purpose of drying grain is to prevent it from going out of condition with the rising temperatures of spring and summer. Because of limited time and limited energy supplies during the harvest period, many facility operators may defer major drying activities until these 3 months if grain moisture content is not too high. The pace is hectic. Since large amounts of grain must be dried within a limited period of time, driers may be operated at higher than normal temperatures. This practice induces increased grain breakage, especially in corn. The end result is an increased amount of grain dust which must be handled. With increased amounts of dust in handling facilities, the risk of explosion increases.

During the latter part of this 3-month period, grain prices are generally rebounding after the harvest slump. Rising prices stimulate the movement of grain from farm storage into commercial storage and on into the marketing system. As mentioned, these three months are high incident months.

The other 2 high incident months - April and May - are months during which large amounts of grain are moving out of storage and into marketing channels. Although less grain is handled during these 2 months than during July and August, an increased risk is still present.

Although empirical support remains to be developed, this discussion indicates that the monthly incidence of explosions is related to the general cycle of yearly elevator activities. Whether these activities cause or only contribute to the incidence of elevator explosions is conjectural. The appar-

ent relationship between yearly elevator activity and explosions reinforces the idea that explosions are a systemic problem in grain handling facilities. As an explanation of the grain dust explosion phenomena, chance clearly assumes reduced importance.

3.1.4. Probable Causes and Locations of Primary Explosions

Explosions in grain handling and storage facilities are caused when suspended grain dust is ignited by an ignition source. When attempting to identify the source of ignition and the location of the initial explosion, past investigations have generally met with little success, and supposition in many cases, has had to replace fact. Chapter 6 discloses that the situation today has not improved. Table 4 presents probable ignition sources for 147 incidents. In 103 of the 250 incidents, probable ignition sources have not been identified.

While all of the listed probable sources are dangerous, welding, cutting and electrical failure demand extra caution.

Table 4.—Probable ignition sources

	No. of facilities	Percent of facilities
Unknown	103	41.2
Welding or cutting	43	17.2
Electrical failure	10	4.0
Tramp metal	10	4.0
Fire other than welding or cutting	10	4.0
Unidentified foreign objects	9	3.6
Friction from choked leg	8	3.2
Overheated bearings	7	2.8
Unidentified spark	7	2.8
Friction sparks	7	2.8
Lightning	6	2.4
Extension cords caught in legs	4	1.6
Faulty motors	4	1.6
Static electricity	3	1.2
Fire from friction of slipping belt in leg	3	1.2
Leaking flammable vapor	3	1.2
Smoldering grain or meal handled	2	0.8
Smoking material	2	0.8
Lighted firecracker	1	0.4
Volatile chemical escaped from soybean processing	1	0.4
Fire from cob pile outside facility	1	0.4
Heating system	1	0.4
Pocket of gas in bin ignited	1	0.4
Extinguishing fire	1	0.4
Leak in gas pipe ignited	1	0.4
Electric control panel exploded	1	0.4
Slipping conveyor belt	1	0.4
Sample size	250	100.0

Table 5 presents the probable sites of primary explosions. In about 43 percent of the incidents these sites are unknown. For those which are known, the most common site for primary explosions is in the elevator leg.

Although all locations where dust is present can be extremely hazardous if given the proper conditions, elevator legs appear to be exceptionally so.

3.2. SURVEYS OF EXPLOSION INCIDENTS

In the foregoing analyses limited information was available for a majority of the 250 recorded explosion incidents. More extensive data was available for smaller samples. This included information on property damage, age of facility, renovations and equipment, facility storage capacity, products handled normally and prior to the explosion, types of employees and contractors

Table 5.—Probable location of primary explosion

	No. of facilities	Percent of facilities
Unknown	107	42.8
Bucket elevator	58	23.2
Hammer mills, roller mills or other grinding equipment	17	6.8
Storage bins or tanks	13	5.2
Headhouse	9	3.6
Adjacent or attached feed mill	8	3.2
Basement	4	1.6
Processing equipment	3	1.2
Dust collector	3	1.2
Tunnel	2	0.8
Distributor heads	2	0.8
Passenger elevator or manlift shaft	2	0.8
Grain drier	2	0.8
Outside and adjacent to facility	2	0.8
Pellet collector	2	0.8
Conveyor system	2	0.8
Receiving pit	2	0.8
Other handling equipment	2	0.8
Processing plant	1	0.4
Down spout	1	0.4
Corn tester	1	0.4
Feed room	1	0.4
Sampler	1	0.4
Storage room	1	0.4
Boiler or feed mill	1	0.4
Electrical switch	1	0.4
Auger conveyor	1	0.4
Electric panel	1	0.4
Sample size	250	100.0

in the facility at the time of the incident, and local fire department responses.

As the size of the sample increased, less data was available for the entire group of incidents. Surveys of 15 and 66 incidents, respectively, were based upon specific data obtained through on-site surveys, interviews, and various source materials from Iowa State University, OSHA, EPA, and from others (refs. 4, 5, 6, 7, 8, 9).

Statistically, these samples are too small to achieve a high degree of confidence. But in view of the lack of information, it seems desirable to present all available data. Conclusions and

recommendations are based, however, on the largest possible sample.

3.2.1. Detailed Survey of 15 Incidents

The 15 explosion incidents summarized in appendix C resulted in 78 deaths, 111 injuries, and an estimated property damage in excess of \$190 million. These 15 explosions occurred during a 28-month period from early 1976 to mid-1978. Of the 15 elevators involved, 6 were export facilities and 9 were inland terminals, country elevators, or grain processing plants. Considering the limited number of export elevators when compared with the total number of U.S. elevators, the large number of recent export explosions is unexpected both statistically and in light of historical experience.

The 15 facilities were constructed from 1892 to 1975 with 3 built since 1963. Substantial additions to physical plants were completed at six facilities with five having been altered since 1963. Fourteen of the facilities were constructed substantially of concrete and steel, and all major additions were of concrete and steel.

Prior to the explosion incidents, only two facilities operated with unmodified, original handling and processing equipment. Thirteen were using either new or rebuilt equipment.

Storage capacities for the facilities ranged from about 70,000 to 6.5 million bushels.

The headhouse was identified as the probable primary explosion site in six of the incidents. Two explosions occurred in both an elevator leg and dust system; one was in a tunnel and one in a warehouse. The three remaining primary explosion sites were unknown.

Six of the facilities were totally destroyed and five sustained major damage. The remaining four suffered less severe damage.

In 3 of the 15 incidents, hot work was identified as the probable ignition source. The circumstances surrounding all the incidents are as reported.

- Incident 1: An engineering report stated that a bin cleaning operation proceeded while welding was in progress, and that this cleaning produced considerable dust which ignited as it was conveyed near the welder.

- Incident 2: Reports by the State OSHA and State Police stated that welding was being done at the time of the explosion. As a result, the State OSHA issued a citation for failure to prohibit welding and cutting in the presence of an explosive mixture of organic dust and air.

- Incident 3: Elevator management alleged that the cause of the ignition was unknown, but a USDA interview disclosed that employees had been cutting out a bearing in a tunnel at the time of the explosion.

- Incident 4: The local fire department reported that the cause was an overheated bearing on the conveyor.

- Incident 5: The fire marshal's report stated that lightning was observed striking the facility just prior to the explosion.

- Incident 6: The State Police, State Fire Marshal, and OSHA reported that the explosion was caused by static electricity. Facility employees observed static electricity jumping from a pipe to a ground cable prior to the explosion. OSHA cited the firm for using an improperly grounded pneumatic conveying system.

- Incident 7: The State Fire Marshal's investigator, the fire department, and facility management all agreed that the cause of the explosion was an arcing electrical motor which fell from its mounts in the basement.

- Incident 8: The facility engineer and manager concluded that tramp metal in an elevator leg caused the explosion. Other suggested causes included a slipping belt or bearing malfunction.

- Incident 9: The OSHA report stated that facility employees noticed a fire in the corncake as it went through an oil extraction process. An attempt was made to put the fire out but during further handling a cyclone collector pulled burning material into the dust system which then exploded.

- Incident 10: An NFPA report presented possible ignition sources as coupler sparks, exhaust sparks, generator sparks, or electric motor sparks from a diesel-electric locomotive. OSHA cited the facility because the locomotive was not dust-ignition-proof, spark arrestors were not on an exhaust pipe, and the locomotive was not operated in a safe manner.

- Incident 11: The facility manager and maintenance superintendent stated that a rock in the leg caused ignition.

- Incidents 12, 13, 14, and 15: The ignition source is unknown.

Ten of the facilities employed no seasonal workers at the time of the incident. Four had seasonal employees working at the time of the incident. One facility could not provide data because of pending litigation.

Ten of the facilities reported outside contractors were not working at the time of the explosion.

sion. Four affirmed the presence of contractors and one facility could not provide data because of pending litigation.

All but one of the facilities had provided training in safety, first aid, or hazard recognition, or a combination of these to their employees and contractors. The extent and quality of the training was not determined. Six facilities indicated no safety meetings were held.

Paid community fire departments responded to eight of the incidents, and six were covered by volunteer fire departments. A privately funded aid group comprised of professional fire fighters and emergency personnel responded at one facility.

In all of the explosion incidents the local fire departments responded in 10 minutes or less from the time they received notification.

3.2.2. Survey of 66 Explosion Incidents and Other Samples

A survey of 66 explosion incidents (the 15 already analyzed plus 51 others) covered incidents from December 1969 through October 1978. With the exception of two incidents, all of those from 1976 through 1978 were included (appendix A). In some cases, additional incidents were included in analyses when appropriate data was available. Comparisons among different samples are provided as a means of assessing the relative reliability of the samples. All results from the sample of 15 incidents have been incorporated into larger samples. The results obtained with one sample generally compare with those obtained in the others.

Products Being Handled

Table 6 shows which products were being handled just prior to each incident. Corn predominates but it should be noted that the second most common group was "none." This indicates that the facility was not handling or processing prior to the incident.

Table 6.—Products being handled at time of explosion, Sample size = 66

	No. of elevators	Percent of sample
Corn	27	40.9
Wheat	4	6.1
Pellets or feed	7	10.6
Milo	7	10.6
None	11	16.7
Soybeans	4	6.1
Soybean products	3	4.5
Aeromycin-soybean meal	1	1.5
Wet milled corn	1	1.5
Rice hulls	1	1.5
Totals	66	100%

Operating at Time of Explosion

Table 7 shows the number of elevators in operation at the time of the explosion incident compared with those that were not. The table clearly shows that machinery need not be operating in order for an explosion to occur.

Table 7.—Operating at the time of explosion, sample size = 66

	No. of elevators	Percent of sample
Operating	55	83.3
Not operating	11	16.7
Totals	66	100%

Probable Ignition Sources

Table 8 shows the probable ignition sources reported for samples of 15 and 66 incidents. All sources require serious attention, but hot work is particularly important.

Table 8.—Probable ignition sources

	15 Incidents		66 Incidents	
	No. of elevators	Percent of elevators	No. of elevators	Percent of elevators
Unknown	4	26.67	17	25.7
Welding/cutting	3	20.00	16	24.3
Hot bearings	1	6.67	7	10.6
Lightning	1	6.67	1	1.5
Static electricity	1	6.67	1	1.5
Electrical	1	6.67	4	6.0
Tramp metal	1	6.67	6	9.1
Rock in leg	1	6.66	1	1.5
Extraction of oil from corn cake	1	6.66	1	1.5
Switch engine on rail dump	1	6.66	1	1.5
Explosive vapor	0	0	2	3.1
Heating system	0	0	2	3.1
Dust system	0	0	2	3.1
Choked leg	0	0	1	1.5
Electric cord in leg	0	0	1	1.5
Volatile solvent escaped from processing of soybeans	0	0	1	1.5
Grain hung up in drier	0	0	1	1.5
Fan blade caused spark	0	0	1	1.5
Totals	15	100%	66	100%

Times of Incidents

Table 9 shows times when explosions occurred in a sample of 66 incidents. Sixty-five of the incidents occurred during daily operations; one occurred when the facility was inactive. The times are based on the assumption that the first work

shift was from 0800 to 1600 hours, the second from 1600 to 2400 hours, and the third from 2400 to 0800 hours. Even though an explosion may have occurred during normal working hours the facility might not have been processing or handling grain.

Table 9.—Times of incidents, sample size = 66

	No. of elevators	Percent of sample
0800-1600 hours First shift	49	74.2
1600-2400 hours Second shift	14	21.2
2400-0800 hours Third shift	2	3.0
Non-working hours	1	1.6
Totals	66	100%

Days Incidents Occurred

Table 10 shows the days of the week on which incidents occurred. Using a sample of 186 explosions, some days have a higher incidence of explosions than others. Most explosions occurred on Tuesday and Wednesday, each having 36 incidents. Friday, with 34, also has a high incidence rate.

The reasons why explosions occurred more frequently on certain days of the week are unknown.

Table 10.—Days of the week, sample size = 186

	No. of elevators	Percent of sample
Sunday	13	7
Monday	24	13
Tuesday	36	19.5
Wednesday	36	19.5
Thursday	26	14
Friday	34	18
Saturday	17	9
Totals	186	100%

Day of the Month

Additional analysis of the 186 incidents compared the day of the month on which they occurred. The average day of occurrence for any month was approximately the 17th. In table 11 this is shown together with the average day of occurrence for each month.

These figures are mathematical averages. In fact, most incidents do not occur on the 17th day, but at some time during the last 2 weeks of a month. Reasons for this trend are unknown.

3.3. ADDITIONAL ANALYSES

The 250 incidents were classified by the Task Force according to State, and States were then ranked in descending order by numbers of inci-

Table 11.—Average monthly day of occurrence, 186 incidents (1958 through 1978)

Month	No. of incidents	Day range	Average day of occurrence
January	15	2 - 31	17
February	16	2 - 27	18
March	12	2 - 27	10
April	15	1 - 30	13
May	21	1 - 28	18
June	10	5 - 30	14
July	18	3 - 30	21
August	23	1 - 31	23
September	14	3 - 26	15
October	15	2 - 31	19
November	9	1 - 30	14
December	18	5 - 31	21
Sample size	186	Avg. day of occurrence 16.9	

dents. The ranking for the top 11 States includes all States having eight or more occurrences during the 21-year period of the study, 1958 through 1978. States having less than eight incidents are not shown.

Additional analyses were made. The numerical rank of each State by number of incidents was compared with other kinds of information available for each State. Any positive correlation resulting from a comparison would indicate the possibility of a causal or contributory relationship.

A ranking of 11 States is used in many of the following sections. Two types of information are generally available when studying the explosion phenomenon: (1) facts resulting from explosions, and (2) factors thought to contribute to the explosion. The first type consists of data such as deaths, injuries, and numbers of explosions per State. The second type includes levels of grain production, facility storage and handling capacities, facility distribution by type, and others which have not been identified.

The hypothesis underlying the analyses is that for large samples over long periods of time, the relationship of one factor to the explosion phenomenon should remain the same if all other factors are held constant. The relationships describing the factors should approximate norms derived for the entire sample.

3.3.1. Explosion Incidents Per State

From 1958 through 1978 explosion incidents in grain elevators and in feed mills were recorded in 32 States and in Puerto Rico (See appendix A.). Eighty-one percent of the recorded explosion incidents took place in 11 States.

Figure 3 shows that the largest number of incidents, 32, occurred in Nebraska. The 10 other States with the largest number of recorded incidents listed in descending order are: Iowa (30), Illinois (27), Texas (24), Kansas (16), Missouri (16),

Figure 3

Top Eleven States Having Explosion Incidents in the Last 21 Years



Figure 3 Top Eleven States Having Explosion Incidents in Last 21 Years

Minnesota (15), Ohio (13), Oklahoma (12), New York (9), and Wisconsin (8). The remaining 21 States and Puerto Rico had from one to four incidents each during this 21-year period.

Four States experienced significantly more explosions during the sample period than any of the others. These are Nebraska with 32, Iowa with 30, Illinois with 27, and Texas with 24. The remainder of the 11 States suffered far fewer explosion incidents.

The ranking of 11 States is used in many of the following sections.

3.3.2. Deaths Per Incident

Throughout the nation, there has been an average of less than one death per incident from 1958

through 1978. The average death rate per incident for those States that have experienced explosions was computed by the Task Force as 0.66. Figure 4 shows 9 of the 11 States experienced fewer deaths per incident than the overall average. The rate for Texas (1.54) is particularly high because of the 18 deaths resulting from an explosion in December 1977 in Galveston, Texas.

The differences in death rates which exist among States may indicate that other significant differences exist. Those differences which can result in differing death rates have not been identified exactly, but may be comprised of variations in State handling systems or in factors affecting the type and severity of the explosions.

Figure 4

Deaths per Explosion Incident in the Last 21 Years

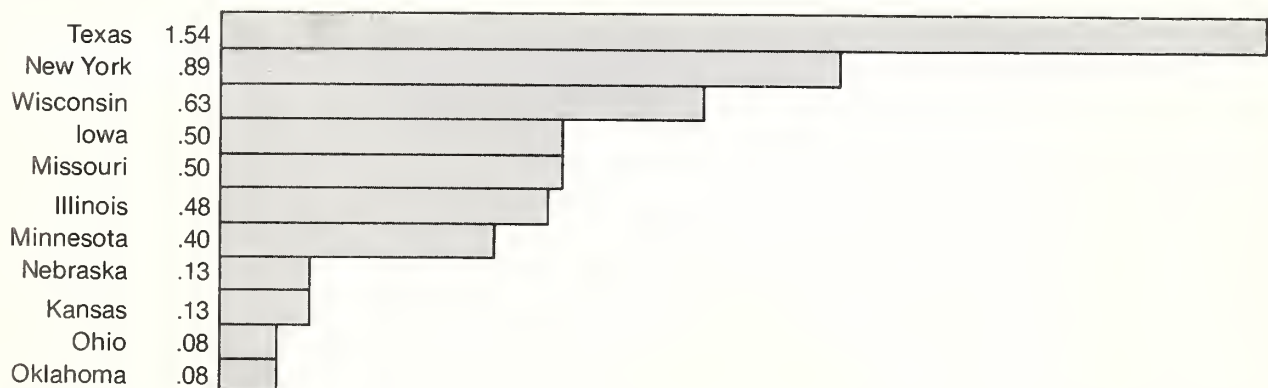


Figure 4 Deaths per Explosion Incident in Last 21 Years

3.3.3. Injuries Per Incident

Across the entire sample injuries averaged about 2.4 per incident. As shown in figure 5, 10 of the 11 States had from 1 to 3.5 injuries per explosion. Missouri was highest with 5.4 injuries per incident. Six States were below the national average.

As with the death rate, the reasons for this variation are unknown.

3.3.4. Off-Farm Commercial Storage Facilities

Eleven States contain 60 percent, 8,995 of 15,065, of all off-farm commercial storage facilities in the United States. Table 12 shows that there is a relationship between 8 of the 11 States with the greatest numbers of recorded explosion incidents and those with the greatest numbers of off-farm commercial storage facilities. Generally, the more grain storage facilities there are per State, the greater the number of explosion incidents.

During the 21 years there was a national average of 1.7 explosions for every 100 off-farm commercial storage facilities. Figure 6 shows only Kansas was below the computed average while Minnesota is the only State with an explosion rate (1.7) which is the same as the computed average. The 9 remaining States all exceed this figure. Nebraska and New York were the two highest with 4.3 and 3.7, respectively.

The reasons for these variations are not known.

3.3.5. Off-Farm Storage Capacity and Explosion Incidents

Off-farm commercial grain storage in the United States is estimated at 6,987,057,000 bushels (ref. Figure 5

Table 12.—Comparison of state rankings; off-farm commercial storage facilities vs. explosion incidents

State	Number of off-farm commercial storage facilities	Ranking	Ranking: number of explosion incidents
Illinois	1,177	1	3
Iowa	1,141	2	2
Kansas	1,086	3	5
Texas	896	4	4
Minnesota	894	5	7
Indiana	804	6	*
Nebraska	740	7	1
Ohio	713	8	8
Missouri	611	9	6
North Dakota	580	10	*
North Carolina	465	11	*

Total (11 States) 9,107 *Not among top 11 States

Numbers of off-farm commercial storage facilities provided by ASCS-ESCS, USDA

10). Approximately 73 percent of this storage capacity is located in 11 States. There is a relationship between these 11 States and those having the greatest number of explosion incidents. Table 13 shows that 9 of the 11 States with the most storage capacity are among the 11 States with the most explosion incidents. Only New York and Wisconsin, which rank 10th and 11th in number of explosion incidents with 9 and 8 respectively, are not ranked in the top 11 States in amount of grain storage capacity.

The number of explosion incidents per State was divided by the 1978 figures for State storage capacity in order to determine the number of explosions per 100 million bushels of storage capacity per State. Figure 7 shows that the 11 States that have the largest number of explosion incidents range from 1.93 explosions to 12.49 explosions per 100 million bushels of off-farm commercial

Injuries per Explosion Incident in the Last 21 Years

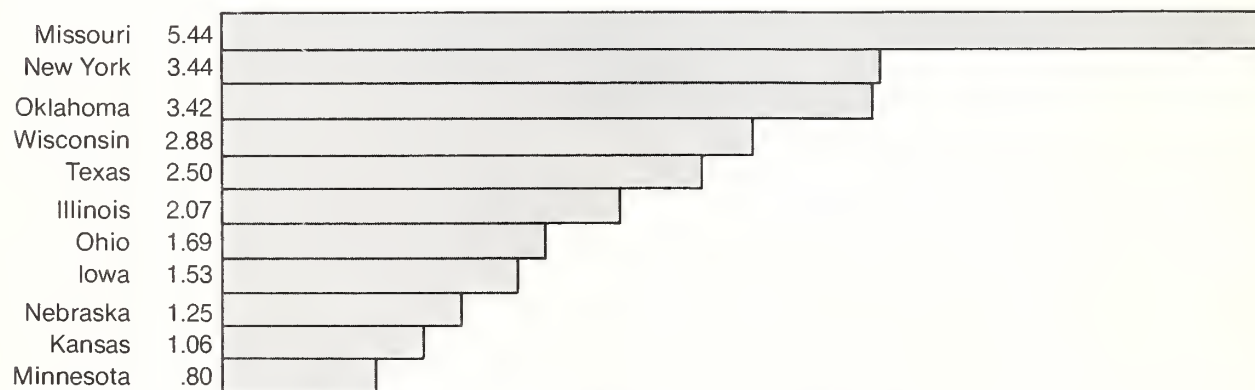


Figure 5 Injuries per Explosion Incident in Last 21 Years

Table 13.—Comparison of state rankings; off-farm commercial storage capacity vs. explosion incidents

State	Commercial off-farm storage capacity (1,000 bu.)	Ranking: storage capacity	Ranking: number of explosion incidents
Texas	837,775	1	4
Kansas	830,602	2	5
Illinois	787,234	3	3
Iowa	634,994	4	2
Nebraska	487,926	5	1
Minnesota	367,914	6	7
Indiana	282,960	7	*
Ohio	244,536	8	8
Arkansas	225,901	9	*
Missouri	201,375	10	6
Oklahoma	205,009	11	9

Total
(11 States) 5,106,226

*Not ranked; less than eight incidents, 1958 to 1978

Source: Commercial off-farm storage capacities provided by ASCS-ESCS, USDA

cial storage capacity. New York has by far the highest explosion rate per storage capacity. The other 10 States are widely scattered from 1.93 to 7.95 explosions per 100 million bushels storage capacity.

In broad terms, off-farm commercial grain storage capacity is related to explosion experience. However, grain storage capacity per State cannot be used alone to predict the number of explosion incidents that States might experience. The relationship indicates that other variables are involved and may include storage capacity, total corn production, facility handling capacity, and others.

3.3.6. Total Grain Production and Explosion Incidents by State

U.S. grain production is centered in 11 States. These account for 73 percent of the total U.S.

Figure 6

Explosions per 100 Off-Farm Commercial Storage Facilities in the Last 21 Years

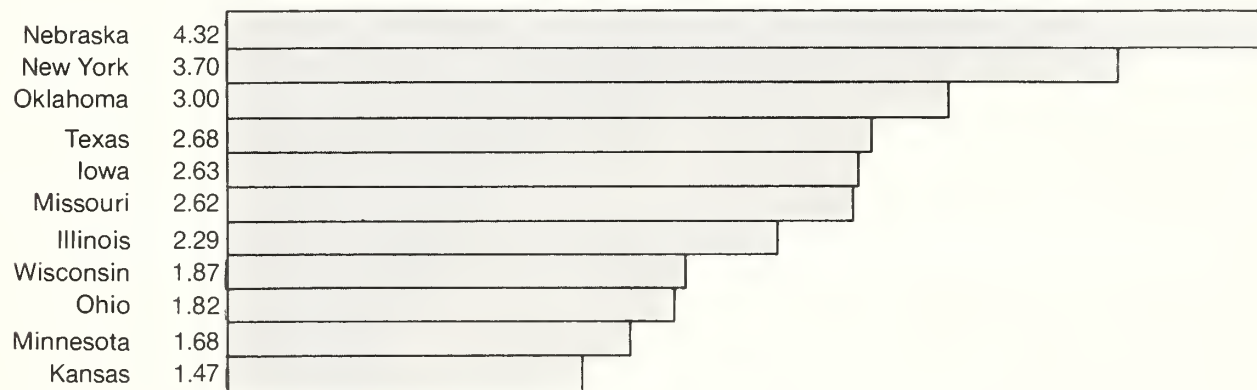


Figure 6 Explosions per 100 Off-Farm Commercial Storage Facilities in Last 21 Years

grain production—9,388,492,000 bushels out of 12,856,760,000 bushels. Table 14 shows crop production figures compiled from USDA's "Crop Production, 1978 Annual Summary" (ref. 11). Table 15 and figure 8 compare State rankings for grain production and explosions. This comparison shows that those with high grain production are also those with high numbers of explosions.

Table 15.—Comparison of state rankings; total grain production vs. explosion incidents

State	Total grain production (1,000 bu.) 1978	Ranking	Ranking: number of explosion incidents
Iowa	1,819,755	1	2
Illinois	1,550,284	2	3
Minnesota	1,034,433	3	7
Nebraska	1,024,759	4	1
Indiana	819,515	5	*
Kansas	701,775	6	5
Ohio	571,795	7	8
Texas	517,679	8	4
North Dakota	500,665	9	*
Missouri	447,327	10	6
South Dakota	400,505	11	*

Total
(11 States) 9,388,492

*Not ranked; less than eight incidents, 1958 to 1978.

Source: "Crop Production, 1978 Annual Summary." FSCS, USDA

Since production figures are for 1978, and the data on explosion incidents reflect a 21-year period, changes in grain production over the years are not accounted for in this material.

3.3.7. Corn Production for Grain and Explosion Incidents by State

Corn was handled prior to nearly 41 percent of the explosions in a sample of 66 incidents. This

(1,000 bu.)

Table 14.—Grain production by state, 1978

Rank	State Name	Rice	Corn	Sorghum	Oats	Barley	Wheat	Rye	Soybeans	Flaxseed	Total
20	Alabama		27,200	1,258	1,200		1,690		42,900		74,248
37	Arizona		5,750	5,694		2,485	9,660				23,589
13	Arkansas	114,065	1,740	12,000	4,015		11,100		112,800		255,720
16	California	57,061	35,406	13,135	5,088	45,600	45,825				202,115
21	Colorado		79,200	9,300	1,760	15,360	57,268	105			162,993
—	Connecticut										
36	Delaware		16,800			1,056	1,008	100	6,860		25,824
34	Florida		19,240				432		9,600		29,272
25	Georgia		75,000	1,247	3,445		3,840	2,530	29,400		115,462
23	Idaho		3,393		3,136	55,800	74,730				137,059
2	Illinois		1,191,030	4,624	15,400	252	35,340	368	303,270		1,550,284
5	Indiana		637,200	975	8,910		31,785	225	140,420		819,515
1	Iowa		1,462,500	1,800	66,700		1,705	150	286,900		1,819,755
6	Kansas		153,000	209,040	4,680	2,640	306,000	315	26,100		701,775
19	Kentucky		119,850	1,426	294	989	6,825	108	42,300		171,792
24	Louisiana	48,750	2,773	578			612		71,000		123,713
43	Maine				2,376						2,376
28	Maryland		57,230		1,242	3,825	3,996	270	11,040		77,603
—	Massachusetts										
14	Michigan		182,250		20,520	893	18,000	600	19,200		241,463
3	Minnesota		643,760		98,820	51,975	93,225	2,352	142,100	2,201	1,034,433
26	Mississippi	19,865	7,560	798			2,015		81,700		111,938
10	Missouri	2,822	191,400	68,000			28,560	175	155,040		447,327
15	Montana		360		10,608	56,375	146,050				213,393
4	Nebraska		740,150	137,250	21,150	1,102	81,600	1,007	42,500		1,024,759
42	Nevada					1,200	1,540				2,740
—	New Hampshire										
39	New Jersey		8,645		384	920	1,188	253	6,180		17,570
35	New Mexico		7,560	12,282		1,425	5,662				26,929
32	New York		47,400		17,700	420	2,625	279	506		68,930
18	North Carolina		121,600	4,472	5,225	3,009	5,940	460	37,200		177,906
9	North Dakota		19,987		65,880	112,700	286,065	6,355	4,758	4,920	500,665
7	Ohio		379,050		24,400	480	43,875	240	123,750		571,795
17	Oklahoma		4,745	17,460	3,420	2,720	145,800	570	5,355		180,070
33	Oregon		1,235		4,200	9,250	51,925	175			66,785
22	Pennsylvania		113,050		18,020	5,875	8,085	512	1,953		147,495
—	Rhode Island										
31	South Carolina		30,250	480	3,900	1,128	2,574	836	32,340		71,508
11	South Dakota		171,520	17,000	102,765	20,905	66,000	6,820	11,895	3,600	400,505
27	Tennessee		43,560	1,224	1,125	442	7,700	38	56,870		110,959
8	Texas	57,013	144,000	227,850	13,760	1,080	54,000	406	19,370	200	517,679
40	Utah		1,440		576	7,336	5,599				14,951
—	Vermont										
29	Virginia		50,430	517	1,620	5,050	5,425	425	12,460		75,927
20	Washington		7,865		1,860	24,700	133,980	63			168,468
41	West Virginia		4,466		504	440	297				5,707
12	Wisconsin		269,500		62,720	1,323	1,560	357	6,880		342,340
38	Wyoming		2,754		2,744	8,253	7,606	66			21,423
Total United States		299,576	7,081,849	748,410	601,477	447,008	1,798,712	26,160	1,842,647	10,921	12,856,760

Compiled from "Crop Production, 1978 Annual Summary" ESCS, USDA.

Figure 7

Explosions per 100 Million Bushels Storage Capacity in the Last 21 Years

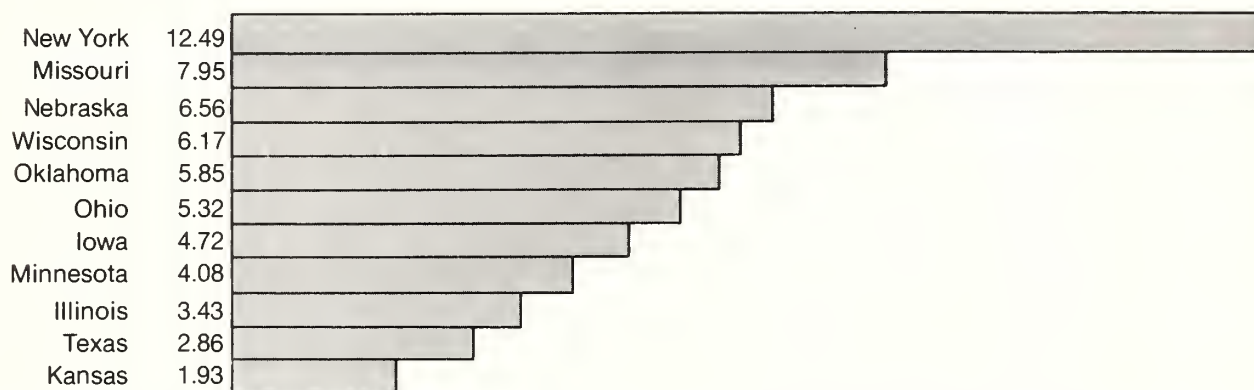


Figure 7 Explosions per 100 Million Bushels Storage Capacity in Last 21 Years

constitutes the largest single group in the sample. State totals for corn produced for grain in 1978 were analyzed. This is presented in table 16 and graphically in figure 9.

Eleven States grew 85 percent of all corn produced for grain—6,021,360,000 bushels out of 7,081,849,000. Eight of these 11 States are also among the top 11 States in explosions.

The production of corn and its handling and storage plays a significant role in grain facility explosions.

3.3.8. Explosions in Feed Mills

From 1958 through 1978, 82 feed mill explosions were reported in the United States. In 1978 the NGFA estimated that there were 10,840 feed

Table 16.—Comparison of state rankings; total corn (for grain) production vs. explosion incidents

State	Amount of total corn (for grain) production (1,000 bu.) 1978	Ranking	Ranking: number of explosion incidents
Iowa	1,462,500	1	2
Illinois	1,191,030	2	3
Nebraska	740,150	3	1
Minnesota	643,760	4	7
Indiana	637,200	5	*
Ohio	379,050	6	8
Wisconsin	269,500	7	11
Missouri	191,400	8	6
Michigan	182,250	9	*
South Dakota	171,520	10	*
Kansas	153,000	11	5

Total (11 States) 6,021,360

*Not ranked in top 11 States

Source: "Crop Production, 1978 Annual Summary," ESCS, USDA

Figure 8

Explosions per 100 Million Bushels Grain Production in the Last 21 Years

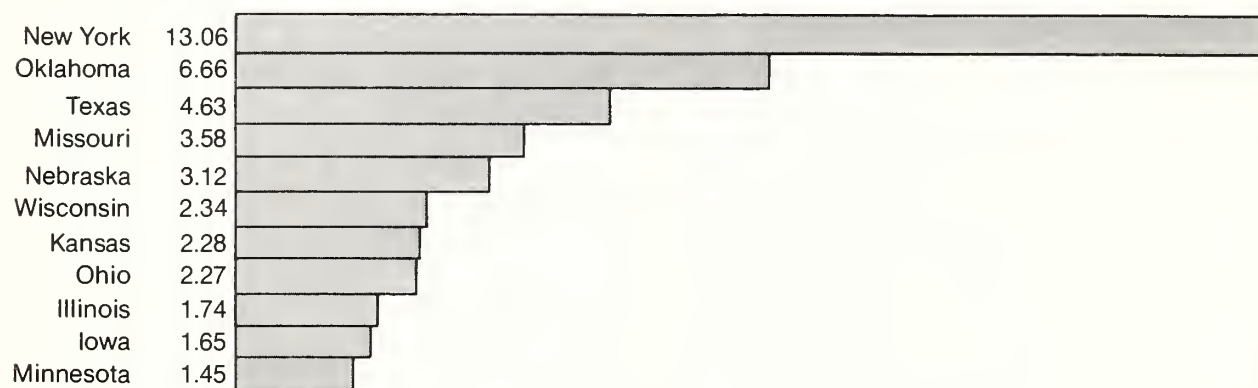


Figure 8 Explosions per 100 Million Bushels Grain Production in Last 21 Years

Figure 9

Explosions per 100 Million Bushels Corn (for Grain) Production in the Last 21 Years

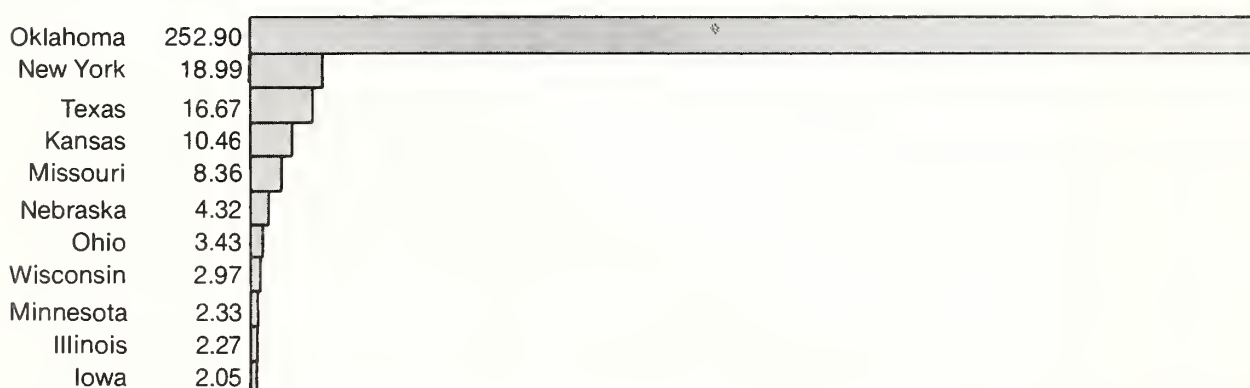


Figure 9 Explosions per 100 Million Bushels Corn (for Grain) Production in Last 21 Years

manufacturing establishments (ref. 13 and appendix J). This is an average of 13 feed mill explosions for every 1,000 operating in 1975. The number of explosions per 100 feed mills should be constant for all States and approximate the national average of 1.32 per 100 per year. This generally holds true for 8 of the 11 States ranked higher in total numbers of explosions (table 17) where they differ from each other by one explosion incident and by one explosion or less from the national average. Three States show a greater incident rate.

Oklahoma had twice as many feed mill explosions per 100 facilities (2.61) and Missouri and New York had three times as many explosions in feed mills per 100 facilities (4.10 and 4.00, respectively).

All nine of the recorded explosion incidents in New York State occurred in feed mills. Nine of

Missouri's 16 explosions occurred in feed mills. Only 3 out of 12 explosion incidents in Oklahoma were in feed mills.

3.4. FIRES AND OTHER HAZARDOUS CONDITIONS

In an effort to enhance the collection of information about the incidence of fire-explosion hazards in grain elevators, the Task Force instituted a hazard reporting system. The reporting system provided USDA field personnel and licensees with the opportunity to immediately report hazardous conditions encountered in the performance of their official duties. A total of 2,750 "Hazard Alert Cards" were distributed to all FGIS and T & W employees as well as to all licensees working under these programs. FGIS safety instructions provided the basis for determining hazardous conditions under this system. Reported conditions are discussed in section 3.4.1.

The particular group of safety instructions which address hazard conditions in grain handling facilities is the FGIS 370-3 series. The most recent instruction is attached as appendix I.

The first instruction of this type was issued in January 1978. This group of instructions permits Federal grain inspectors to refuse official service (conditional withholding of service) if sufficiently hazardous conditions are encountered in handling facilities.

In addition to the hazard reports obtained from the reporting system, NFPA estimated fire experience for 1958 through 1975 is also presented in the material which follows. The present fire experience

Table 17.—Comparison of state rankings; explosions in feed mills vs. total explosions, 1958 to 1978

State	Explosions in feed mills	Ranking: explosions in feed mills	Ranking: total explosions
Iowa	10	1	2
Missouri	9	2	6
New York	9	2	9
Illinois	6	3	3
Kansas	6	3	5
Wisconsin	5	4	11
Nebraska	4	5	1
Texas	4	5	4
Arkansas	3	6	*
Mississippi	3	6	*
Oklahoma	3	6	9

Total 62

*Not ranked in top 11 States

rience as indicated by the reporting system is compared with this past experience.

3.4.1. Hazardous Conditions Reported in Grain Elevators

From April through December 1978, USDA personnel reported 118 hazardous conditions which resulted in the withholding of service. From April through the end of December 1978, there were 86 separate conditions reported at export locations. There were an additional 32 instances of low R.H.: coupled with excessive dust, which resulted in services being withheld. There were also instances of reported bomb threats and false fire alarms. Conditions and reasons are shown in table 18.

It should be noted that the 86 hazard condition reports (excluding bomb threats, false alarms, and R.H. actions) were obtained only from export grain handling facilities, less than 90 elevators. The period of time covered by these reports is less than 9 months. Assuming a limited degree of comparability between the export segment of the U.S. grain handling system and the entire system of more than 15,000 facilities, substantially more than 10,000 such conditions could be occurring throughout the system every year.

3.4.2. Export Fire/Suspected Fire Experience

Twenty-eight fire incidents were reported at export facilities during the 9-month period. An additional 16 suspected fire incidents were reported. This group of 44 incidents consisted of those where substances actually burned with open flames, and those involving smoldering grain, refuse, or other situations not having open flames. All except one of these incidents resulted in FGIS conditionally withholding service by leaving the facility until the condition had been corrected. At the time of these incidents, all were perceived as constituting hazardous conditions.

A list of these incidents is shown in table 19 as are the FGIS Region in which they occurred. (See following figure 12 for a map of the United States showing the FGIS Regions.) Table 20 summarizes this material and shows incident totals by month and by FGIS Region.

The Task Force believes that only a portion of the fire and suspected fire incidents were actually reported during the period of the study because FGIS personnel cannot be aware of all incidents throughout the facility. Although periodic tours are conducted, most FGIS personnel at elevators are stationed in inspection laboratories and in weight control rooms. This situation precludes a

Table 18.—Selected hazard conditions reported at export facilities, April 1978 through December 1978

Non-fire conditions

9	Electrical problem
12	Hot work performed
6	Improper use of electrical tools
4	Spark from switch engines
4	Belts rubbing
3	Hot bearings
3	Employees smoking
1	Smoldering motor
1	Smoldering/hot rollers
2	Smoldering leg pulley
1	Smoke in boot pit
2	Hot pulley
1	Hot drive unit
1	Excessive fumigant odor
1	Blow-down while operating
1	Fuel oil leaked from switch engine into car dump
1	Static electricity
1	Excess grain spills
1	Smoldering dust from hot light bulb
1	Leaking gas
2	Excessive dust present

58 Subtotal

Fires

3	Hot work caused fire
2	Pulley rubbing
5	Smoldering bearing caused fire
2	Electrical switch caused fire
2	Electrical wiring caught fire
1	Hot bearing on belt caused fire
1	Belt in leg slipped and caused fire
1	Head pulley on belt slipped
1	Broken shaft on conveyor
1	Employee smoking caused fire
2	Leg motor or drive smoldering
2	Dryer fire
1	Dust control system motor caused fire
1	Belt on cleaner caught fire
1	Fire on belt near truck lab
1	Fire in ship adjacent to elevator
1	Bearing on leg head pulley overheated

28 Subtotal

86 TOTAL

continuous "fire watch," and prevents complete reporting accuracy.

More than three-quarters of the reported incidents for the 9-month period were concentrated in two FGIS Regions. Region I contains the major part of the Gulf Coast and led with 20 reported incidents; Region II, the Great Lakes and the northern sections of the East Coast, had 14. Seven incidents were reported from 4 of the 12 export elevators in Region III, the Texas Gulf

Table 19.—FGIS export elevator evacuations because of fire or suspected fire by date

April 5, 1978 to Dec. 31, 1978	
Date	FGIS Region
4/10	V
4/12	V
4/17	III
4/18	I
4/27-28	III
4/25	II
5/3	II
5/10	III
5/11	III
6/9	V
6/16	I
6/28	II
6/30	III
7/16	II
7/17	I
7/18	I
7/20	I
7/26	II
8/2	II
8/13	II
8/15	I
8/28	II
8/29	I
9/19	II
9/23	I
10/4	I
10/7	II
10/9	III
10/18	I
10/19	II
10/24	II
10/27	II
10/31	I
11/1	I
11/6	I
11/13	I
11/15	III
11/20	I
11/21	I
12/1	I
12/19	II
12/21	I
12/29	I
12/30	I

TOTALS—44 fires or suspected fires reported at export facilities; 43 evacuations
SOURCE: FGIS Hazard Reports

Coast. Three incidents were reported in Region V, the West Coast. Regions I and II are first and second in numbers of reported incidents, and they are also first and second in volumes of export grain handled.

3.4.3. Comparison of Export Fire Experience with NFPA Estimates

Starting with the FGIS reported fire experience at export locations, the estimated fire incident rate totals about 59 per year. This includes suspected fires as detailed in the previous section. Applying this figure to the estimated 15,000 grain handling

Table 20.—FGIS export elevator hazard reports of fire or suspected fire by region

April 5, 1978 to December 31, 1978					
Month	Region				Total reports
	I	II	III	V	
4/78	1	1	2	2	6
5/78	0	1	2	0	3
6/78	1	1	1	1	4
7/78	3	2	0	0	5
8/78	2	3	0	0	5
9/78	1	1	0	0	2
10/78	3	4	1	0	8
11/78	5	0	1	0	6
12/78	4	1	0	0	5

Source: FGIS Hazard Reports

and storage facilities throughout the United States radically changes estimates of fire incidents occurring each year. Table 21 shows NFPA estimates which ranged from 1,800 to 5,300 fire incidents per year. If the export experience is applied to the entire handling system, an estimate of more than 11,000 fire incidents per year results.

Even acknowledging that some of the export fire incidents did not involve open flames, the estimate remains staggering as it applies to the entire handling system. Open flames, smoldering materi-

Table 21.—Estimated yearly fire experience, 1958-1975

Year	Estimated number of fires
1958	3,200
1959	2,200
1960	2,300
1961	2,100
1962	2,300
1963	2,200
1964	2,000
1965	1,900
1966	2,000
1967	3,000
1968	5,300
1969	4,700
1970	3,000
1971	3,100
1972	2,400
1973	1,800
1974	2,200
1975	2,200
1976	*
1977	*
Totals	47,900

*Data unavailable

Source: NFPA

al, and hot bearings or slipping belts are recognized as possible sources of ignition. In the dusty environments normally encountered at some locations in grain elevators, they become very dangerous sources of ignition. Instead of the estimated 2,700 fires per year, 11,000 may be more realistic. This means 11,000 chances each year for dust explosions.

3.5. CONCLUSIONS

Based on findings involving 21 years of explosion experience, the Task Force concludes the following:

- The greatest number of explosion incidents occurred during the months of August and May.
- The monthly groupings of explosion incidents correlate with the monthly activity schedule of grain elevators.
- Probable ignition sources could be identified in 49 percent of the incidents.
- The largest single group of incidents identified "hot work" as the probable ignition source.
- The probable location of primary explosions was identified in 47 percent of the incidents. The largest single group of incidents identified elevator legs as the probable location of the primary explosion.
- Corn was being handled prior to almost 41 percent of the explosions in the largest sample.
- The second largest group of explosion incidents (almost 17 percent of this sample) consisted of those facilities which were not operating at the time of the incident.
- Most explosion incidents occurred on Tuesdays and Wednesdays; Fridays followed closely. The reasons for this trend are unknown.
- Explosion incidents occurred more frequently in the last 2 weeks of any month. The reasons for this trend are unknown.
- Four States (Nebraska, Iowa, Illinois, and Texas) have experienced significantly more explosions in grain handling facilities than any of the other States for which dust explosions have been reported.
- The average number of deaths and injuries per incident varied according to individual States. Reasons for these variations are unknown.
- There is some comparability between the number of explosions occurring in a State, and the State's total number of grain handling and storage facilities.
- A State's total grain storage capacity alone is not an indicator of the number of explosions which have occurred or are likely to occur in a State.
- Nine of the 11 States with the greatest storage capacity are among those with the most explosions.
- Taken individually the number of facilities and the storage capacity for each State are not

reliable indicators of the number of explosions. Other factors must be involved.

- A relationship exists between those States which have had explosions and the total grain production for each State.
- Eleven States produce 85 percent of all U.S. corn. Eight of those States are in the top 11 States which experienced the most explosions.
- Estimates based on export grain facilities indicate that the numbers of fires per year have been understated. The number of possible ignition sources seems to be greater than originally presumed.
- The development of an adequate data base is extremely important in describing and analyzing explosion experience and in determining effective preventive measures.

3.6. RECOMMENDATIONS

Based on the findings and the conclusions in this chapter, the Task Force recommends the following:

- Prohibit welding, cutting, and other "hot work" entirely within grain handling facilities during operation.
- Apply specific prevention measures to elevator legs.
- Develop and implement standardized design and construction guidelines for all new grain handling facilities. These should include requirements for isolating hazardous processes and areas, dissipating explosion effects through relief venting, and containing fire/explosion phenomena.
- Apply specific handling techniques that address the presence of large amounts of corn and its substantial artificial drying requirements.
- Monitor handling and processing equipment for a designated period after shutdown.
- Determine why particular days of the week and certain periods of the month have higher incident rates than others.
- Study and determine exactly those factors causing and contributing to variations in explosion experience.
- Establish a reporting system for fires and explosions in grain handling facilities which generates an accurate data base.
- Develop analytical capability to describe and predict fire and explosion experience.
- Develop and use a system for technology and information transfer.

Chapter 4

SURVEYS OF GRAIN EXPORT FACILITIES

Following the two export elevator explosions in December 1977, the idea developed that these two incidents may not have been isolated occurrences resulting solely from chance. It seemed possible that fires and explosions could be the logical result of common practices and conditions inherent in the grain handling system. In order to test the validity of this hypothesis, it became necessary to develop an appropriate data base regarding at least one segment of the U.S. grain handling system.

The export grain handling system was selected as the object of a Task Force survey of general conditions and practices. This selection was based on two considerations: (1) the continuing presence of FGIS personnel in grain export facilities, and (2) the limited number of facilities in this segment.

Three ingredients are required for a dust fire or explosion—a sufficient quantity of appropriate dust, oxygen, and an ignition source. The Task Force developed survey questionnaires (appendix D). Specific questions were directed at identifying elevator operating conditions, procedures, and practices which might augment any of the individual parts of this fire/explosion triangle. Other questions addressed operational factors which might contribute to a fire/explosion incident or affect its severity.

During the first 6 months of 1978, FGIS records listed 81 operating, land-based, export grain handling facilities in the United States and Canada handling U.S. grain and also identified several waterbased grain handling facilities called floating rigs which were located on the Mississippi River. The actual number of export grain handling facilities varies from year to year as shown in section 7.2.1. The Task Force obtained responses from 55 of the land-based facilities, primarily through personal interviews with facility managers. These responses are presented in section 4.1. Appendix E summarizes this data.

The enforcement of environmental air quality standards has often been cited as contributing to

grain elevator explosions. It has been argued that prohibiting the release of dust particles into the air outside the facility has resulted in a dangerous buildup of flammable dusts inside the grain elevator. The closing of windows and doors which had previously remained open reduced the amount of naturally available explosion relief venting. This is said to have increased explosion severity and resulting damage.

While this premise can be neither proved nor disproved, the enforcement of environmental air quality standards has resulted in an increase in dust control measures in grain elevators. An additional survey was conducted to show the application of dust collection and control technology in grain handling facilities. The survey was limited to export facilities. The Task Force collected data through the use of questionnaires. Copies of these questionnaires are presented in appendix F. Findings are presented in this chapter and summarized in appendix G.

This chapter also contains the following information:

1. General background,
2. Results of personal interviews with dust collection equipment manufacturers, and
3. Estimates of dust generation in export facilities.

4.1. EXPORT ELEVATOR SURVEY

The following section presents the findings of the Task Force survey of export grain handling facilities. The material is summarized in appendix E. Included with these findings is general explanatory material about grain elevators and their operation.

Grain elevators are a collection of structures and mechanical devices providing a vital link in the chain between grain producers and users. They serve as collection and distribution centers for grain after it is harvested on the farm and as it moves through the various grain handling and

marketing channels. In addition to their distribution functions, grain elevators provide other services such as initial processing, merchandising—including weighing and quality determinations—and storage. Initial processing includes drying, cleaning, aerating and turning the grain to preserve its condition, fumigating to reduce insect infestation and damage, and blending lots of grain to achieve desired quality or end use characteristics.

The merchandising function of grain elevators is important. Besides weighing to determine how much grain is actually on hand, elevators also make quality determinations which disclose what is being handled. Grain elevators also tend to reduce the impact of the discrepancies which can arise between grain supply and demand: this is achieved through grain storage. Because elevators can receive and store grain for which there is no immediate need, they can also supply stored grain to consumers whose grain receipts and stocks are inadequate. Another major merchandising service is provided through transferring grain from one means of conveyance to another, from truck to hopper or box car, from hopper car to barge, and so on.

By providing storage, grain elevators facilitate transfers between sellers and buyers in the cash as well as the future contract grain markets. Elevators may also provide public warehousing.

At present, the U.S. grain handling system consists of an estimated 15,065 off-farm grain handling and storage facilities. These facilities bear the brunt of handling, processing, and storing the huge amounts of grain used domestically or exported from the United States. In 1976, this figure, total grain disappearance, was nearly 233 million metric tons (ref. 13).

Elevators can be divided into three basic categories - country elevators, inland terminals, and port terminals. Each category provides a different mix of those services previously outlined.

Chiotti and Verkade propose a slightly different classification system consisting of regional elevators, terminal elevators, and processing plant elevators, with the possibility of a fourth category, country elevators (ref. 4). This is based on the fact that over the years once-prevalent country elevators—in 1945, there were 16,500 country elevators in the United States (ref. 12)—have either been consolidated, increased in size, or ceased operations in response to the need for increased efficiency. This has resulted in fewer, larger facilities serving larger producing areas—hence, the need for a “regional” category of grain elevators.

At present, the NGFA has estimated that there are 9,472 country elevators (ref. 14). Chiotti and Verkade describe a typical “country” elevator as having storage capacity of 100,000 bushels or more with many exceeding 1,000,000 bushels (ref. 4). Grain elevators cannot be precisely differentiated on the basis of storage capacity alone.

Before proceeding further, an apparent discrepancy in the number of U.S. grain handling, processing, and storage facilities should be understood. This discrepancy arises because the facilities cannot be segregated on the basis of their particular activities. The subject is discussed further in appendix J.

If it is assumed that all of the facilities listed in the various sources are separate, there would be a total of 21,536 grain handling, processing, and storage facilities. The difference between this and the USDA estimate of 15,065 is 6,471. This figure, 6,471 or about 43 percent of all U.S. facilities, is believed to represent the approximate number of multiuse facilities in the United States. The total of 15,000 facilities is used throughout this report.

4.1.1. Layout and Construction

The physical layout of grain elevators can be separated into two functional areas—storage and processing. Handling functions are usually performed in the processing areas although they also extend into storage areas. Figure 10 shows a typical elevator layout.

The processing area or workhouse may be from 100 to over 200 feet high and contain equipment for receiving, elevating, cleaning, weighing, and distributing. The term workhouse is commonly used interchangeably with headhouse.

The construction materials used in grain elevators now in operation generally are of three different types. Reinforced, slip-formed concrete is commonly used for almost all large elevators. Smaller elevators are often constructed of wood or metal framing covered with metal sheathing. Some of the older facilities may be constructed of wood, either with or without the metal sheathing.

The time of initial construction of the 55 export facilities surveyed ranged from 1892 to 1978. Thirty-five percent of the facilities were built prior to 1931; 7 percent were constructed from 1931 to 1945. The majority, 58 percent, had been constructed since 1946; 27 percent were built after 1962.

Portions of several facilities were constructed with wooden structural members, either “crib” or “ballon” construction, and generally with galvanized iron sheathing. Almost all of the facilities had

Typical Grain Elevator

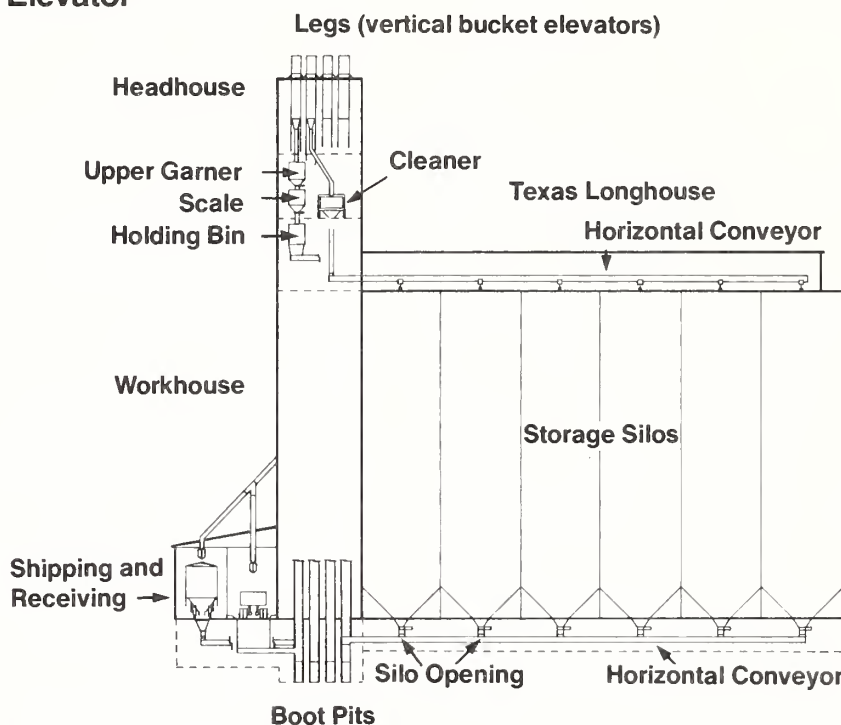


Figure 10 Typical Grain Elevator

been constructed with reinforced concrete and steel.

Fifty-eight percent of the facilities had completed major alterations since 1946. These alterations consisted of additions which increased handling and/or storage capability.

4.1.2. Storage Capacity

Thirteen percent of the facilities have grain storage capacities of less than 2 million bushels. Sixty-two percent have from 2 to 6 million bushels storage capacities, and 22 percent can store between 6 and 10 million bushels. Three percent have storage capacities greater than 10 million bushels.

Sixty-seven percent have increased their total storage capacities through additions to the physical plant. Thirty-one percent reported no change in storage capacity and 2 percent experienced a decrease in total storage capacity.

4.1.3. Products Handled

Fifty-one percent of the facilities listed wheat as the grain comprising most of their total thruput volume. Thirty-eight percent listed corn, 2 percent listed barley, 7 percent listed soybeans, and 2

percent listed sorghum (used interchangeably with milo in this report).

Fifty-three percent of the facilities reported that they handled grain screenings. Twenty-two percent handled meal and 18 percent handled pelletized material. One facility handled substantial quantities of dry chemicals.

4.1.4. Grain Exports

Grain export figures are presented and explained in Section 7.2. These figures are presented according to export areas and are based on data from export inspection certificates issued by FGIS. These figures represent only a part of the total export facility thruput volume. A percentage of grain and grain byproducts received at export facilities reenters the domestic marketing and use system. Accordingly, derived total thruput figures, indicative of "system loading" (section 7.2.3.) for the export handling system, would be somewhat higher than indicated by exports alone.

4.1.5. Equipment

Export terminal grain receiving capabilities vary. All export facilities can receive and unload

“hopper-bottom” railroad cars but only 69 percent can receive box cars. Seventy-six percent can receive truck traffic, *i.e.*, truck lift or dump. Forty percent have marine legs and therefore barge receiving capability.

Actual receiving rates are also variable. These ranged from 13 percent of the facilities having a maximum operational capability of 15,000 bushels/hour or less to 4 percent exceeding 100,000 bushels/hour. Forty-seven percent are in the 16-45,000 bushels/hour range and 36 percent receive from 46 to 100,000 bushels/hour.

There is more uniformity in the area of load-out or shipping equipment. All elevators can load-out ships or in some cases barges. The type and size of vessel which can be loaded varies. Seventy-eight percent can load railcars and 46 percent can load trucks.

Twenty-two percent of the facilities have a maximum load-out capability of 40,000 bushels/hour or less. Forty-five percent fall in the 41-60,000 bushels/hour range and 18 percent are in the 61-80,000 bushels/hour range. Fifteen percent have a maximum load-out capability exceeding 80,000 bushels/hour. In most cases actual average load-out rates are substantially lower than the maximum figures reported above.

Eighty-four percent of the facilities have grain cleaners or scalpers. Forty percent have grain driers.

In all cases main hopper scales are contained in the upper portion of facility headhouses or in other structures such as “weighing towers” in some of the newer facilities. Eighty-six percent of the facilities have weight control rooms situated either in the upper portions of the headhouse or at ground level adjacent to the headhouse.

Modern bulk grain handling techniques require that each facility have the capability for internal conveyance of grain or other products between receiving, loading, storage, and processing sites. Although several alternatives are available, internal grain conveyance systems usually are composed of lengths of flexible belting of varying widths. Two general classifications of conveyance systems exist, horizontal and vertical.

Horizontal systems, known as belts, employ continuous belting which passes over a line of support and drive roller assemblies. An additional type of horizontal system is the “drag type” conveyor which uses a continuous chain with paddles which passes through an enclosed housing. Vertical systems, known as elevator legs, employ a drive or head pulley and an idler, or tail pulley. Buckets or cups are attached at regular intervals

to a continuous length of flexible belting. Except for an opening at the grain entry point (boot), the entire assembly is completely enclosed in a light-weight housing. After grain has been elevated to the desired height, horizontal conveyors or gravity flow systems with metal ductwork and spouting are used to move it to processing and storage locations. Inclined conveying systems as a replacement for elevator legs are gaining wider acceptance and use in the grain industry.

4.1.6. Facility Operation

Twenty-two percent of the facilities operate around-the-clock during the entire year. Four percent operate on a 24-hour basis only during period of peak grain movement. Twenty-nine percent of the facilities operate 16 hours per day throughout the year. Thirteen percent operate on a 16-hour per day basis seasonally. Eighteen percent of the facilities operate one 8-hour shift throughout the entire year. Fourteen percent work one 8-hour shift on a seasonal basis.

Thirty-one percent of the facilities are located in the Great Lakes area and are limited in their export shipments to water-borne carrier. These facilities only export grain during the Great Lakes navigation season, approximately April 15 to December 1.

4.1.7. Labor Organizations

Various labor organizations represent some employees at 49 of the facilities or 89 percent. Those facilities having collective labor bargaining can be further divided into two groups: (1) those drawing their labor from a union pool (15 West Coast port facilities or 31 percent), and (2) those having a traditional labor arrangement (34 facilities or 69 percent). Eleven percent of the facilities are nonunion. Nine percent have combinations of union and nonunion labor employees.

4.1.8. Employee Safety

Seventy-one percent of the facilities have written instructions addressing various aspects of safety. However, composition of these instructions varies. Forty percent of the facilities have written instructions covering the need for and use of protective equipment such as dust masks, hard hats, or safety harnesses. Thirty-six percent of the facilities have instructions setting out proper work methods and machinery use. Fifty-five percent have written instructions covering acceptable procedures for performing welding or other hot work, and prohibiting smoking in the facility.

Forty-two percent of the facilities have employee safety training programs. Actual employee training ranges from a brief orientation at hiring to certified first aid instruction. Eighty-four percent of the facilities held meetings at which safety topics were discussed. Meetings were frequently limited to management.

4.1.9. Contingency Plans

Fifty-five percent of the surveyed facilities have written emergency instructions. All of these have emergency telephone contact numbers (police, fire, etc.). Forty-five percent have detailed procedures for securing the facility in case of an emergency shutdown. Thirty-one percent define employee emergency responsibilities and functions.

Twenty-two percent engage in periodic practice evacuation drills. Forty-two percent have specified meeting places outside of the facility following evacuation and 22 percent provide for an employee headcount to determine missing or injured.

4.1.10. Early Warning Equipment

About 80 percent have devices which indicate malfunctioning machinery. Eighty-two percent use meters which, when properly connected to a drive motor, indicate the amount of current used to operate that motor. Eighty percent employ overload indicators and 73 percent have automatic shutoff devices. These devices cease operation of all related feed, handling, or processing equipment when one piece of equipment fails.

Thirty-eight percent of the facilities are equipped with either manual or automatic emergency alarm systems. All of the facilities have various kinds of fire extinguishers on the premises, but the number located in each facility varies. Fifty-eight percent of the facilities are equipped with some sort of standpipe system for use in extinguishing fires.

4.1.11. Other Safety Equipment

Thirty-three percent of those facilities having dust control systems employ blast dampers to confine dust fires and explosions in the system to the immediate area surrounding the ignition site. Blast dampers should not be confused with blast gates which are used to regulate air flow in the dust control system. Dust control will be discussed more fully in sections 4.2. through 4.3.

4.1.12. Facility Maintenance

Twenty-two percent of the facilities reported that on the average they employed less than three

maintenance employees per shift. Forty-seven percent reported maintenance employees averaging from three to six per shift and 19 percent from seven to nine per shift. Twelve percent average more than nine maintenance employees per shift.

Twenty percent of the facilities have maintenance personnel stationed at the facility on a 24-hour basis. Thirty-one percent have maintenance personnel on duty for 16 hours per day. Forty-nine percent have maintenance personnel on duty only during one 8-hour shift each day.

Thirty-five percent of the facilities have some sort of written instruction regarding maintenance procedures and scheduling. Twenty-seven percent require that maintenance employees use a checklist to ensure that maintenance operations are performed on specified pieces of equipment. Forty-four percent of the facilities maintain some sort of maintenance log which details past performance of maintenance operations.

Forty percent of the facilities authorize hot work through the use of a written permit system. Permits are issued prior to starting the work.

4.1.13. Housekeeping

Thirty-seven percent of the facilities employ no personnel specifically assigned to housekeeping; 26 percent average less than three per shift. Twenty-two percent employ from three to six persons per shift; 6 percent have from seven to nine housekeeping employees on each shift. Nine percent employ more than nine persons per shift for housekeeping.

Thirty-three percent employ housekeeping personnel during only one 8-hour shift per day. Eleven percent have housekeeping personnel working 16 hours per day, and 19 percent have housekeeping personnel working around-the-clock. Eighteen percent of the 55 facilities require that employees be responsible for housekeeping functions in their assigned work areas.

Twenty percent have some form of written housekeeping instructions. Fifteen percent issue checklists to their housekeeping employees to ensure that housekeeping functions are not overlooked. Eleven percent maintain housekeeping logs which record past performance of housekeeping functions.

4.1.14. Conclusions

Comparing some of the prevalent conditions in the export grain handling system with well-documented hazards that contribute to increased risk

of dust fires and explosions, major conclusions are:

- Many elevators are more than 30 years old. As a result of increasing grain exports, both old and new elevators are engaged in a continual round of building additions to increase handling or storage. Increased handling capacity exceeding the design capacity of the original physical plant can place excessive demands on older equipment and structures.

- Sixty-two percent of the export facilities surveyed have from 2 to 6 million bushels of storage capacity. Coupling this relatively limited storage capacity (in terms of thruput) at most export facilities with the current scarcity of rail transportation and the increased use of "unit trains," the export handling system could be taxed to the limit of its capabilities. This concept is developed more fully in section 7.2.

- Thirty-eight percent of the surveyed facilities listed corn as the grain most handled. In 1976 corn comprised nearly 46 percent of total U.S. grain exports, including grain products and rice. This indicates an uneven distribution in the handling of corn in the export system. Compared with other grains, corn sustains a relatively high percentage of breakage and dust generation in the course of normal handling. This presents a significant hazard in those export facilities where corn predominates. (See also section 7.2.2.)

- Twenty-two percent of the facilities normally operate around-the-clock. An additional 29 percent operate at least 16 hours per day. The demand for services provided by export elevators is high because of the rapid growth in grain exports and the large volumes handled. Because 41 percent of the system normally operates with more than one working shift or at least an extended single work shift, the export handling system can be seen as approaching the maximum limit of its ability to provide services. Although full-time operation allows more efficient use of physical plant, any resulting advantage may be offset by increased labor costs caused by lower per capita productivity rates. Increased levels of housekeeping and maintenance are also required and further reduce the benefits of extended operation. Increased human error is another possible factor.

- Services provided by the export handling system vary widely as do the rates at which those services can be provided. As an integral part of the operation in all export grain handling facilities, grain weighing devices, hopper scales, are located in the upper levels of the headhouse. In

those facilities using inclined belts instead of legs, these scales are located in "weighing towers." Eighty-six percent of the facilities have weight control rooms located in or directly adjacent to the headhouses. The use of electronic or semielectronic weighing systems and remote input/output terminals minimizes the number of persons required inside elevators to perform weighing. Weight control rooms could be moved outside of and away from the headhouse. This would reduce the number of persons required inside the facility and minimize the chance of human error. In a serious dust explosion, casualties would be reduced.

- Various labor organizations represent employees at 89 percent of the facilities. Although exact statistics are unavailable, cursory review of several union contracts discloses a lack of emphasis on safety and little uniformity.

- Written instructions pertaining to safety vary. Although more than two-thirds of the facilities have some kind of safety instruction, contents are not standard. Twenty-nine percent of the facilities have no written safety instructions.

- Only 55 percent have written instructions regarding acceptable procedures for performing welding or other "hot work."

- Fifty-eight percent of the facilities do not provide any safety training for their employees.

- Eighty-four percent of the facilities held meetings at which safety topics were discussed. However, frequency of the meetings, topics discussed, and employee attendance were not standardized.

- Nearly half of the facilities surveyed did not have contingency plans. For those that did, content and scope varied widely. If an explosion or serious fire occurred, any reduction in property and casualty losses would be left to chance.

- The use of early-warning equipment in export grain handling facilities varies widely. Although devices to indicate and handle equipment malfunction are prevalent, their application in any one facility is generally limited. Many different types of early warning devices are used.

- Only 38 percent of the facilities surveyed were equipped with emergency alarm systems. The other facilities have no means of notifying employees of an emergency situation except through the use of intercoms and/or telephone systems.

- One-third of those facilities having dust control systems employ blast dampers in the systems. Blast dampers can be important in the event of a

fire or explosion in the system since they can isolate the phenomenon in one part of the system.

- Nearly half of the facilities employ maintenance personnel during one 8-hour working shift only. The average maintenance staff consists of three to six employees. Although this corresponds closely with the figure for hours of daily operation, it may preclude a rigorous system of preventive or operational maintenance.

- Only 35 percent of the facilities had written instructions regarding maintenance procedures and scheduling. Forty-four percent of the facilities used a logging procedure to document performance of maintenance functions.

- "Hot work" permits were not required at 60 percent of the facilities.

- Maintenance programs could be improved through standardization, the use of written instructions including checklists and performance logging procedures, and by increasing the maintenance staffing beyond the minimum level needed for emergency maintenance. In many instances routine preventive and operational maintenance functions could be reassigned to equipment operators. Although this would probably require increased operator training, it could effectively increase the actual size of the maintenance staff at little increased cost.

- Thirty-seven percent of the facilities do not employ any personnel specifically for the purpose of housekeeping. Twenty-six percent assign three persons or less per shift. Therefore, 63 percent of the surveyed export elevators employ three persons or less specifically for housekeeping. Even with dust collection systems housekeeping is critical to adequate dust control.

4.1.15. Recommendations

Based on the findings and conclusions in this section, the Task Force makes the following recommendations:

- Establish standards for retrofitting and/or renovating grain handling facilities.

- Study methods for more equitable and more efficient distribution of grain within the handling system in order to balance the supply of services with demand.

- Develop and apply specific techniques suited for the handling of corn that will reduce breakage and dust generation and dispersal. Consider increased application of techniques such as containerized shipments, choke feeding, deeper layers of grain on conveyor belts, and others as feasible.

- Perform remedial housekeeping and maintenance functions during daily downtime as part of a comprehensive maintenance and housekeeping program. If sufficient downtime is unavailable, elevators must designate some daily period for performing these functions.

- Provide periodic employee breaks in order to minimize fatigue and boredom and thus reduce the incidence of human error.

- Relocate weight control rooms, as well as inspection laboratories, offices, locker rooms, dining areas, and maintenance shops away from the facility. If possible, this distance should be equal to the height of the tallest point of the facility.

- Conduct regular safety meetings and encourage all facility personnel and contractors to participate in developing, implementing, and monitoring safety programs.

- Implement improved safety measures and practices as developed through safety meetings and other means.

- Standardize safety programs, safety techniques, and levels of safety practice, so far as possible throughout the grain industry.

- Provide employees with improved safety and hazard recognition training and couple such training with extensive and standardized safety programming and implementation.

- Develop and implement standardized safety operations plans and contingency plans with emphasis on those items listed in appendix H.

- Install emergency alarm systems.

- Develop and implement improved, more comprehensive levels of preventive and/or operational maintenance programming. Provide sufficient personnel for each operating shift to permit prompt performance of required maintenance work.

- Develop and implement improved, more comprehensive housekeeping programs. Provide sufficient personnel for each operating shift to permit prompt performance of required housekeeping.

4.2. DUST COLLECTION OVERVIEW

This section presents general information regarding the collection and control of dust in grain handling facilities. Mechanical collection equipment is used extensively to increase the effectiveness of facility housekeeping. Many factors affect how this equipment is designed, installed, and used. Conclusions and recommendations for this section are presented under section 4.3.

4.2.1. Background

Dust control is emphasized as a significant means of preventing dust explosions in grain handling facilities. Argument arises concerning exactly what level of dust control is adequate for any particular facility. Determining effectiveness is difficult, but each facility operator must consider the basic results he wishes to achieve and select the appropriate equipment and applications.

In this section two terms are used to denote different levels of dust control. The first, dust collection, refers to methods and equipment applied to specific sources. Dust is collected at those points in the grain handling or processing stream where grain dust is normally dispersed into the air. Dust control refers to the results achieved when dust collection and other measures are used to limit dust accumulation/dispersal in a facility. These two terms are not interchangeable and must not be confused because it is possible for a facility to have very effective dust collection but still have poor overall dust control.

Whenever grain is received into, transferred within, or shipped from grain handling facilities, dust is generated and escapes from handling equipment, carriers, and storage bins. Within the facilities this dust accumulates on walls, ceilings, floors, spouting, and equipment. On the outside of the facilities dust escapes into the atmosphere during the loading and unloading of carriers and from facility openings to the outside, such as doors, windows, etc.

Aggravating this inherent dust problem is the fact that when grain arrives at a facility it usually contains dust generated during previous handling and processing. Different lots of grain contain different amounts of dust depending on how the grain was handled and processed previously. The type of grain is also a major factor, for in the course of normal handling and processing, some grains simply produce more dust than others. The handling and processing of corn presents the greatest problem to the U.S. grain handling system. Corn production and handling exceeds that of any other grain and it tends to be the dustiest grain. Other grain dusts cannot be disregarded. In addition to posing a possible health problem for exposed workers, all grain dusts can be ignited if the proper conditions are provided.

The presence of dust in grain and as a consequence in grain handling facilities is an inescapable fact. Its flammability makes it an excellent fuel for fires and/or explosions. If it is not controlled, grain dust threatens the safety of workers and the continued operation of a facility.

Effective dust collection and control can improve conditions inside facilities where dust is a problem by:

1. Improving working conditions and thus employee health and morale
2. Reducing maintenance costs
3. Controlling rodent and insect infestation
4. Minimizing fire and explosion hazards, and
5. Reducing insurance costs.

Dust control can be achieved with a combination of housekeeping activities, applied dust collection, and other control measures. Many grain handling facilities rely heavily on the use of mechanical collection equipment in dust control programs. This reliance has increased in recent years.

4.2.2. General Description

A dust collection system consists basically of a motor-driven fan which creates the airflow necessary to capture dust particles and carry them through duct work to a collector. The dust from this collector is either removed to a storage bin or returned to the grain. Hoods or canopies are installed over transfer points where dust is generated. Sufficient negative pressure to pick up dust particles is maintained in each hood. The layout of the ductwork is designed to fit available space within the facility and is sized to keep air velocity sufficient to prevent the settling of dust particles within the duct.

Many types of collectors are available. The two types most frequently used are cyclones and cloth-type bag filters. A cyclone is a mechanical dust separator that relies on cyclonic action within a chamber to separate dust from the airstream by centrifugal force. Cyclones can be 85 percent efficient, but they allow some collected dust to be emitted into the air. A cloth-type bag filter consists of a series of cloth-covered tubes arranged inside a sheet metal housing.

The dust-laden air passes through the tubes leaving the dust on the cloth. A continuous internal cleaning mechanism is sometimes provided for cleaning the filter tubes while the dust system is in operation. Because the bag filter collector is about 99 percent effective, it has become the predominant means for controlling dust emissions to the outside environment. Some facilities have installed cyclone collectors before their bag-type filter collectors to separate the larger particles of dust and permit easier operation of the bag filters.

The operation of a dust collection system consisting of multiple hoods and many branches of ducts requires a means of distributing airflow between the branches and providing adequate airflow at each hood. This can be accomplished by two methods—the balanced design method or the blast gate method. In balanced design or the static pressure balance method, the desired rate of airflow is obtained by a suitable choice of pipe sizes, elbow radii, etc. With the blast gate method, the gates must be adjusted after installation in order to achieve the desired airflow at each hood. The static pressure balance method is recommended for collection of highly toxic particulates, explosives, magnesium, and other explosive dusts because any possible accumulations caused by blast gates are eliminated (ref. 19).

4.2.3. Design and Installation Requirements

The Task Force found that there was a scarcity of published guidelines on the specifics of dust collection for grain handling facilities. Existing guidelines refer primarily to the need for dust collection at specific areas without discussing how the collection is to be accomplished. These guidelines discuss requirements for the proper installation and the safeguarding of the systems against known fire and explosion hazards but minimum design requirements are not usually specified. Designers must rely on guidelines discussed in general industrial ventilation manuals. In addition, it is necessary for these designers to follow parameters and data acquired from actual installation and testing of dust collection systems.

Common Practices

Two dust collection filter manufacturers and one installation contractor provided information concerning design and installation of dust control equipment.

Manufacturers of dust collection equipment provide necessary design and installation services to grain handling facilities, but facility operators are not required to utilize these services when they purchase the equipment. When a grain handling facility desires to install or upgrade a dust collection system, operators either request the installer or manufacturer to design the system or submit their own proposed designs. The designs which the facility may provide can either be prepared by company engineers or by independent designers. If the operators request the manufacturer or installer to design the system, they provide a detailed plan of the facility, specifically indicating the areas

where the dust should be collected. The companies review the designs or plans submitted and provide necessary advice to the operators. If the designs or plans do not provide for proper equipment operation or effective collection, recommendations for improvement are made. If the operators insist that the installation be done according to their own design specifications or plans, there is no existing requirement or obligation for them to utilize the design of the manufacturer.

Upon request, manufacturers will install the equipment that they sell. The operators may, however, contract the installation work to other firms or perform it themselves. Manufacturers or installation companies supervise their own installation work to assure that the equipment is installed and operates as intended. They will, if requested, supervise the installation work performed by facility employees.

Guidelines

There are no specific industrial standards for the manufacture of dust collection equipment or for the design of dust collection systems. The requirements for the manufacture of filters are vague, but do state a minimum ratio of the area of the cloth bags in a bag-type filter to the volume of air it handles. The manufacturer of duct work and related equipment generally follows the guidelines presented in the *Industrial Ventilation Handbook* (ref. 19) published by the American Conference of Governmental Industrial Hygienists. Designers rely on experience gained from installation and operation of dust collection equipment to develop their minimum requirements for equipment and systems. These minimum requirements will vary among companies.

NFPA No. 61B, "Standards for the Prevention of Fire and Dust Explosions in Grain Elevators and Bulk Grain Handling Facilities" (ref. 20), recommends guidelines for dust control. These guidelines suggest dust collection at specific points within facilities. The standards also suggest that the installation of mechanical dust collection equipment be done in accordance with two other NFPA standards, NFPA Nos. 66 and 91 (refs. 21 and 22). Although all three standards recommend specific equipment and installation requirements, none detail specific design procedures for duct design, hood design, exhaust volumes, conveying velocities, system selections, fan requirements, etc. Instead, the standard for the installation of mechanical dust collection equipment, NFPA No.

91, accepts construction, workmanship and installation of duct and system components that conform to the Industrial Ventilation Handbook (ref. 19).

The Industrial Ventilation Handbook discusses overall ventilation requirements. A few guidelines are presented for dust collection in grain handling facilities. The handbook suggests air volumes and hood designs for some specific equipment, but notes that necessary air volumes will vary considerably depending on the degree of enclosure, the flow rate of grain, and the amount of dust.

4.2.4. Dust Removal and Recirculation

In 1918 the Bureau of Chemistry of the USDA (chapter 2) proposed several solutions for the prevention of grain dust explosions. One of those recommendations emphasized that "Every effort should be made to collect and remove the dust from the grinding mill and surrounding atmosphere" (ref. 1). This report marked the beginning of an awareness by the grain industry that mechanical means for dust removal were necessary to minimize the fuel needed for an explosion—dust. In implementing this important preventive measure, the persistent problem of weight discrepancies in the grain industry was further aggravated.

Weight discrepancies have always been experienced among shippers and receivers of grain when attempting to maintain the integrity of weights between elevators and/or markets. As a result, commercial guidelines established by the transportation and grain industries for weighing grain did not permit the installation of mechanical dust collection equipment for fear of possible abuses. As the result of a study in 1927 by the Underwriters Laboratories on the removal of dust in grain elevators, NFPA recommended the installation of systems of cyclone dust collectors. This recommendation was included in the first NFPA code dealing with the prevention of dust explosions in terminal grain elevators (ref. 4). Mechanical dust collection is now the basic means of minimizing dust accumulations in grain handling facilities.

Commercial guidelines or requirements for weighing grain eventually were revised to permit use of mechanical collection equipment for removing dust. These guidelines do not now permit the removal of all of the dust that is collected. As before, to preserve the integrity of weights determined by shippers and receivers of grain, these guidelines do not allow mechanical removal of dust before weighing inbound or after weighing

outbound grain. Currently it is common practice to collect dust and return it to the grain during handling. Grain dust may be collected and returned to the grain many times from its first handling to its export or other end use.

No Federal agencies have regulations which mandate the return of collected grain dust to the grain. Erroneous beliefs persist that Federal regulations exist, particularly those of USDA, which require the return of collected dust. Before passage of the U.S. Grain Standards Act of 1976, the guidelines or requirements for weighing grain were developed under an independent system established by the AAR to insure accurate weights. These requirements were enforced by various State agencies or by private concerns. USDA's role during this period was to license persons to weigh grain at grain elevators voluntarily regulated under the U.S. Warehouse Act. At that time, USDA was not authorized to supervise or control weighing of grain.

Since 1976, USDA has been authorized by the Grain Standards Act (as amended) to supervise and perform the weighing of grain at both interior and export locations. The previous system established by AAR for supervision is utilized in conjunction with Federal supervision at export locations to provide control nationwide. Although USDA has developed and implemented requirements for weighing grain, they do not address the return of collected grain dust. Since there is a lack of legislation or regulation in this matter, USDA has accepted the existing dust collection methods at each export elevator.

Conclusions from research material, the International Symposium on Grain Elevator Explosions (section 7.1.), and discussions with the insurance industry, the grain industry, Government agencies, and dust collection manufacturers all emphasize that the reintroduction of collected grain dust into the grain is hazardous. The Grain Standards Act Advisory Committee, a consultative body comprised of industry, Federal, and State officials, recommended that dust normally removed during grain handling processes be permanently withheld from the grain stream and be considered an unavoidable loss. The principal reasons for this consensus are as follows:

1. Use of bag-type collectors usually results in very fine particles being reintroduced. It has been demonstrated that the smaller particle sizes are easier to ignite.

2. Collection by bag-type collectors usually results in very dry particles being reintroduced. Drier particles are easily ignited.

3. Continued recirculation of dust and the constant creation of additional dust through handling, compounds the overall dust control problem. If collected dust is not returned, dust collection systems could purge the facilities of dust rather than continually handling it.

Manufacturers, designers, and installers of dust collection equipment agreed that there is no serious problem in designing new systems, redesigning existing systems, or installing necessary equipment which would not allow the reentry of dust to the grain stream. These representatives further agreed that the prohibition of dust recirculation is simply a matter of additional cost.

Recently the Federal Government sought a voluntary prohibition of the reentry of collected dust into the grain stream. On July 18, 1978, Assistant Secretaries for both USDA and OSHA jointly signed a request to the industry to prohibit the recirculation of grain dust (appendix K). The request was with the concurrence of EPA. On November 15, 1978, following another serious grain dust explosion in which several persons were killed and injured, the Administrator of FGIS again urged elevator operators voluntarily to cease the recirculation of dust in the system (appendix L).

4.2.5. Dust Generation

The collection of grain dust and the prohibition on returning the collected dust to the grain stream may be an expedient solution to the fire/explosion problem in grain handling facilities. The possibility that this removal of grain dust from the facilities will become more prevalent throughout the industry raises two major questions: (1) How much dust is actually generated through the operation of the handling system? and (2) Can this amount of dust be utilized?

Estimates of the amount of grain dust generated in the export handling system for the period 1975 through 1978 are presented in table 22. These estimates are based solely on inspected exports of wheat, corn, and soybeans. These three grains comprise about 92 percent of total inspected grain exports. The table was prepared by taking the export volume figures presented in tables 28 through 31 and multiplying them by 0.1 percent.

This computation yielded a volume figure in bushels for dust. Since dust may have various densities, a maximum of 30 pounds and a minimum of 20 pounds per bushel were used. Each density figure was multiplied by the derived bushel figure to yield the total poundage of dust which

could be generated. These amounts are presented for the four FGIS regions where grain is exported.

The maximum estimate for the period 1975 through 1977 does not exceed 60,000 tons per year. The 1978 maximum estimate was based on the inspected export figures for the first 6 months. Actual inspected export figures exceeded this projected total.

Table 22 assumes that dust generated for all grains amounts to 0.1 percent (refs. 12, 23, and 24) of the total volume of grain handled. Computations can be performed using the weight of grain handled rather than the volume. Results obtained by using the weight of the grain are about double the results obtained using volumes. Both resulting estimates of dust present in export grain are less than 100,000 tons.

Even when handled similarly, different grains produce different amounts of dust (ref. 19) and each successive handling creates additional dust. The amount of dust present in export grain depends on this accumulation as well as on the various amounts of each grain handled. In one set of experiments, Martin and Stephens (ref. 24) reported that with similar handling, the amount of dust generated by wheat was negligible when compared with that generated by corn.

Normal cleaning operations seem to reduce overall grain dustiness (ref. 24), but the precise effect of successive handling, processing, and storage operations cannot be determined. The estimate of 0.1 percent used in this section may be a conservative estimate of dust present in export grain.

Basing estimates on these considerations the amount of dust present in export grain should not be greater than 100,000 tons per year. This tonnage exceeds the largest figure in table 22 by 68 percent and applies only to the export handling system. The major problem in using this dust lies in the fact that it is distributed throughout the U.S. export handling system. There may be enough dust in only a few locations to sustain an industrial process. Transporting dust to a centralized processing location means additional handling and cost, and increases the possibility that this highly flammable material might be ignited.

Any processing, such as pelletizing, to facilitate handling would increase the cost of the end product. Also, in terms of sustaining industrial processes, 100,000 tons of grain dust is fairly insignificant. While it is more than enough to create serious explosion hazards in export grain handling facilities if not collected and removed, it may not

Table 22.—Export system derived dust generation at 0.1% of inspected exports*

	1975				1976				1977				(Projected)	
	Dust generated at 20 lbs./bu. (tons)	Dust generated at 30 lbs./bu. (tons)	Dust generated at 20 lbs./bu. (tons)	Dust generated at 30 lbs./bu. (tons)	Dust generated at 20 lbs./bu. (tons)	Dust generated at 30 lbs./bu. (tons)	Dust generated at 20 lbs./bu. (tons)	Dust generated at 30 lbs./bu. (tons)	Dust generated at 20 lbs./bu. (tons)	Dust generated at 30 lbs./bu. (tons)	Dust generated at 20 lbs./bu. (tons)	Dust generated at 30 lbs./bu. (tons)	Dust generated at 20 lbs./bu. (tons)	Dust generated at 30 lbs./bu. (tons)
Region I—Total	13040	19550	16720	25085	15900	23850	18140	27210						
South Atlantic	130	200	190	280	95	140	100	145						
Mississippi River	11720	17580	15060	22590	14810	22210	15980	23970						
Eastern Gulf	1185	1780	1465	2200	1000	1495	2065	3100						
Region II—Total	7230	10850	8040	12055	7860	11795	9930	14895						
Canadian Lakes	60	85	200	300	210	315	455	680						
U.S. Lakes	3025	4535	2725	4090	3140	4710	3905	5855						
North Atlantic	1010	1515	1080	1625	875	1310	1350	2025						
South Atlantic	3140	4710	4030	6045	3640	5460	4225	6340						
Region III—Total	5305	7955	4460	6690	4165	6245	6400	9600						
North Texas	4845	7270	4050	6075	3870	5805	5545	8315						
South Texas	460	690	410	615	295	440	855	1285						
Region V—Total	3475	5210	3620	5430	2880	4325	5210	7815						
Columbia River	2190	3285	2355	3530	2125	3190	3065	4600						
Puget Sound	670	1005	780	1170	475	715	1185	1775						
California	615	925	485	725	280	425	960	1445						
Totals (I, II, III & V)	29050	43565	32840	49260	30805	46215	39680	59520						

*Figures are rounded to the nearest 5 tons and are derived from inspected exports of wheat, corn, and soybeans only.

be enough to justify the large capital investment required for its processing and marketing by these same facilities.

Empirical data suggests that an export elevator with a well-designed and operated dust collection system may collect from one-third to one-half of the grain dust present. This collection rate would have to be improved considerably to make extensive processing practical.

Some grain dust is used currently in the manufacture of animal feeds. Based on a 1976 survey of the feed manufacturing industry USDA published the following figures (ref. 17) pertaining to grain, grain by-products, and oilseed meal components of manufactured feeds:

Table 23.—Manufactured feed ingredients; United States—1975

Origin	Amount (tons)
Grains	37,104,412
Oilseed meals	11,319,410
Grain by-products	8,055,255
TOTAL USE	56,479,077 tons

If the 100,000 tons of dust estimated to be present at export were to be utilized in animal feeds, it would comprise only 0.18 percent of those components used in the manufacture of such feeds.

Other alternatives such as direct burning or the production of ethanol remain to be studied. Because of the relatively limited amounts of grain dust expected to be available, any such enterprise would probably remain local or regional in scope.

Given the basic assumptions concerning the rate of dust generation in the grain handling system, 0.1 percent, total grain dust present in the handling system is relatively small in comparison to the total amounts of grain handled. It is, however, dangerous and the possible effects of this dust can be disastrous if it is not removed and handled carefully.

4.3. DUST SURVEY FINDINGS

An analysis of existing data disclosed little information about the procedures and equipment utilized by grain handling facilities to collect dust. A survey was conducted of export grain elevators within the United States. Most information was obtained through interviews, but some questionnaires were answered by elevator personnel and FGIS field personnel.

Of the 73 export elevators contacted, 67 responded. All elevators reported using mechanical

dust collection equipment in their programs of dust control. Fourteen elevators did not report the locations where they returned collected dust to the grain. One elevator did not report the manner in which collected dust was returned to the grain.

4.3.1. Elevator Dust Collection

Dust collection equipment varied by types of collectors, numbers of collectors, and locations within facilities. The bag filter collector was the most commonly used. Seventy-two percent of the facilities used bag filter collectors and four percent of the facilities used cyclone collectors. Combinations of the bag filter and cyclone collectors were installed in 24 percent of the facilities.

The number of collectors installed in these facilities ranged from 1 to 125 separate collectors. Fifty-one percent installed no more than 8 collectors; 27 percent installed from 9 to 16 collectors; 16 percent installed 17 to 32 collectors; and 6 percent installed more than 32 dust collectors.

Most mechanical dust collection systems did not provide for collection from all equipment or from all locations within the facilities. Each facility installed dust collection systems within the headhouse, but the types of equipment and their locations varied. Eighty-four percent of the facilities had systems installed within their unloading facilities while 55 percent had mechanical collection on equipment in the galleries and/or outside spouts. Twenty-seven percent had installed dust collection systems on handling equipment in storage areas.

4.3.2. Dust Removal and Recirculation

Several export elevators removed collected dust from their facilities, but the majority returned collected dust to the grain stream. Thirty-six percent of the export elevators reported that none of the dust was returned to the grain while the remaining 64 percent said that collected dust was returned to the grain. Twenty-one percent returned all dust while 43 percent returned part of the collected dust.

The locations for the return of collected dust varied in the 29 export elevators which return a part of the dust to the grain stream. Thirty-five percent of these elevators reported that they introduced dust only within the headhouse and the unloading and shipping facilities. Because of inbound weight considerations 45 percent of these elevators returned the dust to the grain stream only within unloading facilities. Seven percent returned the dust only at shipping galleries and/or

spouts, while 10 percent reported that dust was introduced to the grain stream at both unloading and shipping facilities. None reported that dust return sites were limited to headhouse locations or to related handling equipment.

Various methods were used by the 43 facilities which returned collected dust to the grain. Fifty-three percent reintroduced the dust by means of gravity, transferring the dust to the grain from a collector by means of a conduit usually placed downstream from where the dust was collected. Twelve percent utilized screw conveyors and 5 percent used pneumatic systems. A combination of these three methods was utilized at 28 percent of the reporting facilities. One of the elevators did not report the manner in which its collected dust was reentered.

Fifty-two of the elevators provided storage facilities for dust. These consisted of storage bins or centralized baghouses. At 58 percent of these facilities, the collected dust was stored either in or directly adjacent to the headhouse. Centralized baghouses or storage tanks were located less than 100 feet from the headhouse at 28 percent of the facilities. The remaining elevator reported that the collected dust was conveyed directly to carriers for shipment without any intervening storage.

The 53 export elevators that did not return all collected dust to the grain stream reported they shipped varying amounts of dust from their facilities. Twenty-five percent shipped less than 50,000 pounds per week. Thirty-four percent shipped from 50 to 100,000 pounds per week, 9 percent from 100,000 to 150,000 pounds per week, and 6 percent more than 150,000 pounds per week. Although all 53 elevators responded, the amount of dust shipped from 26 percent of the elevators could not be determined from the information provided.

4.3.3. Collection Equipment Maintenance

Maintenance, repair, and installation work on dust collection equipment typically is performed by personnel with no specialized training, and bag-type filters are not regularly examined or replaced.

Routine Maintenance

Forty-seven percent of the export elevators reported routine work was performed by facility employees and that none had received specialized training regarding dust system maintenance and repair.

Thirty-four of the facilities (53 percent) responded that routine dust system maintenance was performed by trained personnel. Seventeen of the 34 facilities reported that their maintenance employees had been trained by the dust system manufacturer, 8 reported that professional engineers provided the training, and 7 of the facilities provided the training to their employees. Two of the facilities responded that their maintenance employees had received training but the exact kind could not be determined.

Major Maintenance

Thirty-three percent or 22 facilities reported they used trained maintenance mechanics for major kinds of dust system repair or installation. Of these 22 facilities, 13 had maintenance staffs trained by the manufacturer, 4 had been trained by professional engineers, and 4 facilities provided their own training. One elevator reported that its employees had received some training, but did not provide any details.

Sixty-seven percent of the facilities did not employ specially trained facility employees for major dust system repair and maintenance. Ten of these facilities used their general maintenance staff, 29 used contractors, and 6 used some other means which was not described.

The elevators that reported having bag-type filter collectors did not change filter bags regularly. These elevators reported that the bag filters were not examined during each operating shift for tears, clogs, and such. Thirty-three percent of the facilities reported that dust system bag filters were changed only as needed following visual checking, which was not scheduled on a regular basis. Forty-two percent reported that bag filters were checked daily, 16 percent weekly, and 9 percent checked filters on a monthly basis.

4.3.4. Conclusions

Based on these facts the Task Force concludes the following:

- Present dust control methods do not specifically address the unique characteristics of corn or the large volumes of corn present in the U.S. handling system.
- Effective dust collection and control can improve conditions inside handling facilities where grain dust is a problem.
- Adequate dust control consists of a combination of mechanical dust collection, housekeeping operations, and other control measures. Export

handling facilities seem to have emphasized mechanical dust collection rather than a balanced combination of all three.

- Mechanical dust collection systems are being designed primarily for the collection of dust from specific equipment and locations rather than being designed to control dust throughout the facility.

- Although some guidelines exist, there are no standards for the design, manufacture, installation, operation, or modification of dust control systems and their component parts. This situation permits an adequate system to be installed but operated improperly. Also, a competent installer may install inadequately designed and ineffective systems.

- Accumulation of dust in handling facilities over a period of time indicates an inadequate dust control program.

- There are no Federal regulations requiring the return of collected dust to the grain from which it was originally removed.

- Reintroduction to the grain stream of collected dust and the recirculation of this mixture of dust and grain increase the fire/explosion hazard in handling facilities.

- Present technology can be applied in retrofitting, renovating, or installing dust control equipment in existing facilities. The cost of complete dust control remains the major constraint.

- Handling and processing corn generates substantially more dust than wheat. It is normally the dustiest of the three major grains—corn, wheat and soybeans.

- Corn is the predominant grain in all segments of the U.S. handling system. (See also sections 3.5 and 3.6).

- Each successive handling, storage, and processing operation performed on a lot of grain contributes additional dust to that grain. Even though normal cleaning operations seem to reduce overall levels of grain dustiness, the cumulative effect of all of these operations on the amount of dust present in export grain has not been determined.

- Dust present in export grain is estimated to be less than 100,000 tons per year.

- Currently dust collection systems are not designed and operated to extract all dust which is present in the grain being handled.

- In actual practice, handling facilities may remove less than half of all dust present in the grain being handled.

- If all dust thought to be present in export grain were extracted, this amount could be ab-

sorbed by existing industrial processes such as the feed manufacturing industry, distillers, etc.

- Alternative uses for grain dust may be limited by the need to transport the dust and collect it at locations where processing is available.

- All of the 67 export elevators in the dust survey use mechanical dust collection equipment. The bag-filter type dust collector is used exclusively in 72 percent of the elevators.

- The numbers of collectors in use at any facility vary from 1 to 125 separate collectors.

- Most mechanical dust collection systems fail to collect dust from at least one or more pieces of dust-producing equipment or from all dusty locations in the facility.

- The majority of export elevators return at least a part of collected dust to the grain from which it was extracted.

- Methods for returning collected dust and locations where this dust is returned vary widely. Weight considerations are a major factor in determining where collected dust is returned to the grain stream.

- Gravity flow is the method most commonly used for returning collected dust to the grain stream.

- Of those elevators with storage facilities for collected dust, a majority locate these dust storage areas either in or adjacent to headhouses. Such locations constitute potentially dangerous fire/explosion hazards.

- Levels of dust collection system maintenance and the training of personnel to perform repair and maintenance vary widely. Many persons have no specialized training. This holds true for both major and routine maintenance and for repair functions.

- The majority of elevators using bag-filter type collectors do not inspect filter bags every shift or even every day.

- Most export elevators seem to have serious weaknesses in their collection equipment maintenance programs as well as in their overall dust control programs.

4.3.5. Recommendations

Based on the findings and conclusions resulting from sections 4.2 and 4.3, the Task Force recommends the following:

- Develop and implement improved and more comprehensive dust control programs that encompass mechanical collection, housekeeping, and other control measures.

- Determine the effectiveness of dust control programs by gauging dust accumulation in grain handling facilities over a period of time. A dust control program would be considered effective or ineffective based on the presence or the lack of dust accumulation.

- Develop standards for design, manufacture, installation, operation, and modification of dust control systems and their component parts.

- Develop and implement increased levels of monitoring for design, manufacture, installation, operation, and modification of dust control systems and their component parts.

- Require grain handling facilities to collect dust from all dust-producing equipment or dusty locations within their facilities.

- Prohibit the reintroduction and recirculation of collected grain dust in grain handling facilities.

- Study and determine possible incentives, including tax relief, direct subsidy and low interest

loans, which could be used to promote increased levels of dust control in grain handling facilities.

- Develop requirements for dust collection systems that specifically address the unique characteristics of corn and the large volumes handled.

- Do not recirculate dust collected from grain at any stage of the handling system from harvest to end use.

- Study and determine existing and additional uses for grain dust including the feasibility and the impact of these uses.

- Require all dust storage to be located outside and a safe distance from the grain handling facility.

- Require each grain handling facility to develop and to implement a dust control program which includes mechanical dust collection, house-keeping, and other control measures. These dust control programs should have a comprehensive maintenance program with a routinized system for repair, maintenance, inspection, renovation, etc.

Chapter 5

INVESTIGATION, ENFORCEMENT, AND EMERGENCY PREPAREDNESS

Innumerable Federal, State, and local authorities exercise individual responsibilities with regard to safety in the workplace and the enforcement of known explosion prevention methods. In addition, there exist varying levels of emergency preparedness.

The Task Force surveyed the circumstances surrounding explosion/fire incidents to determine the levels of safety, health, and environmental quality enforcement and the adequacy of explosion investigations. Information concerning responsible agencies and the extent of their activities was also developed and analyzed with regard to emergency preparedness.

5.1. INVESTIGATIONS OF EXPLOSIONS

After a grain handling facility explosion many Federal, State, and local agencies are responsible for conducting investigations to determine the cause and the circumstances surrounding the explosion. These agencies have many collateral and overlapping responsibilities which may complicate or hinder efforts to complete comprehensive investigations. These collateral or overlapping responsibilities can include:

1. Determining whether Federal or local criminal laws have been violated.
2. Establishing whether explosives were involved.
3. Investigating rumors and reports of wrongdoing.
4. Conducting search and rescue operations.
5. Performing necessary fire fighting operations.

Investigative reports were obtained for 15 of 55 grain handling facility explosions from 1976 through 1978. These reports were evaluated along with the results of onsite interviews with facility

managers and responsible Federal, State, and local authorities. The purpose of this evaluation was to determine the effectiveness of the original investigations in establishing the exact circumstances and causes for these 15 explosions.

5.1.1. Occupational Safety and Health Administration, U.S. Department of Labor

The Department of Labor's OSHA is authorized under the Occupational Safety and Health Act of 1970 (29 U.S.C. 651) to investigate catastrophes and other accidents. This Act does not require that all accidents and catastrophes be investigated nor does it specify which particular ones they are authorized to investigate. The OSHA has adopted the policy of inspecting all job-related fatalities as promptly and thoroughly as resources and priorities permit. Responsible OSHA Area Directors or delegated State Directors determine which catastrophes or other accidents are to be investigated.

The OSHA Field Operations Manual (ref. 25) specifies that accidents should be investigated if there are:

- One or more fatalities; or
- Five or more employees hospitalized for more than 24 hours (a catastrophe); or
- Significant publicity is involved; or
- Specific instructions have been issued for fatality/catastrophe investigations in connection with a National Office Special Program.

In addition, there are general guidelines which emphasize investigations of accidents that recur frequently or involve extensive property damage.

The primary purpose of OSHA investigations of on-the-job accidents is to determine whether (1) a violation of OSHA safety and health standards contributed or may have contributed to the occurrence, (2) the accident could have been avoided

had proper safety and health regulations been enforced and followed, and (3) OSHA standards should be revised to remedy the hazardous working condition(s) that caused the accident/catastrophe (ref. 25).

All investigations are conducted using general inspection procedures as required in an accident investigation. The investigation can be conducted by a team of experts or a compliance and safety health officer with expertise in the particular condition that may have caused the accident.

OSHA's general inspection procedures (see section 5.2.1.) require its inspectors to determine if employers are complying with safety and health standards and are furnishing workplaces free from recognized hazards. The established inspection procedures provide the administrative requirements for performing workplace inspections but do not establish minimum procedures or details required for accident investigations. Investigations are not normally directed toward identifying causes of grain facility explosions.

OSHA has no authority to direct rescue operations, control access to a disaster site, or direct debris removal. As a direct result, physical evidence which might provide information about the cause is usually destroyed or displaced during search and rescue operations. The direction of rescue operations is primarily the responsibility of the employers, local political subdivisions and/or State agencies. OSHA does have the authority to monitor and inspect the working conditions of personnel engaged in rescue operations to make certain that all necessary precautions are being taken to protect the lives of the rescuers.

The examination of the 15 explosion incidents disclosed that 12 explosions were investigated by OSHA and/or the responsible delegated State agency. Of the three explosions that were not investigated, one resulted in a fatality and media coverage. The remaining two explosions did not result in any fatalities but one incident did injure four persons.

A review of OSHA's accident investigations for 3 of the 12 explosions found that the explosion investigations were conducted by compliance officers who had no specific training in investigating this type of catastrophic accident. Their training only dealt with the investigation of personal injury accidents.

OSHA's accident investigation procedures for these three incidents primarily were directed toward determining compliance with safety and health standards and ensuring that workplaces were free from recognized hazards. The investiga-

tions were concluded without exhausting all investigative leads and without determining causes. Investigating officers concluded inspections when it was determined that the OSHA requirements had been met or further material was not available to support additional citations.

Although each of the three facilities was cited for violations under the OSHA Act, many of the violations appeared to be unrelated to the causes of the explosions, lack of fire alarms, means of egress, posting of safety instructions, signs, etc. In no case was it established that a violation definitely contributed to and/or caused the explosion.

5.1.2. Federal Bureau of Investigation, U.S. Department of Justice

The FBI is authorized under Chapter 4, of the U.S. Criminal Code, "Importation, Manufacture and Distribution of Explosive Materials" (18 U.S.C. 841 *et. seq.*), to investigate violations of Federal law by threat of or use of explosives. The FBI is authorized to investigate interstate receipt or transportation of explosives to damage, destroy, or attempt to damage property, or to kill or injure individuals. The FBI has primary jurisdiction where it is claimed or indicated that an extremist or terrorist group committed a violation with explosives. The FBI is not required to investigate any of these violations.

Normally, the FBI does not conduct investigations of explosions in grain handling facilities. The FBI investigated only 1 of the 15 grain elevator explosions reviewed and in this case an extremist group had claimed responsibility. Investigative procedures consisted of an examination of the site and some interviews with available witnesses. After it was determined that explosive devices were not involved, the investigation was suspended.

The FBI field personnel explained that they did not conduct investigations into 14 other explosions because they had not been requested to do so by responsible local authorities, or because they had determined that they did not have jurisdiction in the matter. They further advised that they relied upon State Fire Marshals or local fire authorities to request FBI assistance in investigating explosions in grain handling facilities. Investigations would be initiated only if there was an indication that explosive devices were actually involved.

5.1.3. Bureau of Alcohol, Tobacco and Firearms, U.S. Department of the Treasury

The AT&F is also authorized to investigate explosions where there is reason to believe that explosive devices were used. AT&F derives its authority from Title 18, Chapter 4. of the U.S. Code. According to a written agreement with the FBI, AT&F has been delegated primary responsibility for investigating possible violations with explosives except those involving extremist or terrorist organizations. Where explosive devices are suspected, AT&F is authorized to inspect the site of the accident or fire. If it is determined that explosive materials were not involved, AT&F is authorized to continue inspections to determine if the incident was caused by accidental means.

The AT&F investigated 5 of the 15 explosion incidents using onsite visits and interviews with available witnesses. They examined the available debris at four locations and performed laboratory analysis in three cases. The AT&F determined that explosive devices were not involved in four cases. Their investigation continues for the remaining explosion. None of the investigations completed by AT&F determined the specific ignition source.

AT&F field personnel stated that they normally relied upon State Fire Marshals or other responsible authorities to request AT&F assistance. When a determination is made that no explosive devices were involved AT&F suspends direct investigative efforts.

AT&F headquarters personnel said that they have many agents and many laboratory specialists with extensive training and work experience in explosion investigations and prevention. They advised that upon request by USDA or other Federal agencies, investigations of explosions of grain handling facilities could be made. However, facility management can prohibit access to these facilities. Unless it can be shown that explosives have been used, or were suspected of being used, legal efforts to require access to an explosion site may be unsuccessful because of jurisdictional problems.

5.1.4. Fire Authorities

Local fire authorities are supervised by a State Fire Marshal or similar authority within 47 States. These authorities are responsible for establishing training programs for fire investigation and providing special investigative services for fires of suspicious or unknown causes. In many cases,

these responsibilities have been delegated to fire authorities in larger State municipalities. In the remaining three States in the United States local authorities are responsible for providing their own training and conducting required investigations.

Normally, certain authorities are required to investigate the cause, origin and circumstances of fires within defined jurisdictions. These authorities can include:

- (1) Chiefs of municipal fire departments;
- (2) Chief fire officers of special fire districts (volunteer or mutual aid);
- (3) Town marshals in towns having no fire department; and
- (4) Sheriffs in unincorporated areas.

Investigations are conducted where possible at the lowest responsible level to determine the cause and circumstances surrounding a fire or explosion. Under certain circumstances, such as when fatalities result, the local fire authority is required by most State laws to report the incident to the State Fire Marshal or some other delegated authority such as a municipal arson division, etc. State Fire Marshals or other delegated authorities then may conduct fire-scene examinations to determine whether detailed investigations are required. If circumstances warrant a detailed investigation is initiated.

State Fire Marshals

Seven of the 15 explosions were investigated by State Fire Marshals. The investigations consisted of interviews with available witnesses for each explosion, detailed examination of debris for five explosions, and laboratory analysis for four explosions. A possible cause was identified for five of the explosions; in most cases the identification of causes was based on information obtained from local and Federal authorities.

The Fire Marshals interviewed by the Task Force stated that their staffs had extensive training and experience in incendiary fire and arson investigations but had not been specially trained for grain facility explosion investigations.

Local Fire Chiefs

Six of the 15 explosions were investigated by local fire department officials. These investigations were limited in scope but did include some interviews and the examination of debris. Several reports consisted only of fire call records. The local fire officials interviewed available witnesses for

each explosion examined the available debris, and conducted a laboratory analysis for one explosion.

None of the local fire chiefs interviewed by the Task Force had any specific training for investigating grain elevator dust explosions. Two of the 15 explosions were not investigated by any of the responsible authorities.

5.1.5. Police Authorities

In each State, the Governor or Executive Head of each local jurisdiction has the primary responsibility for those functions necessary to protect the lives and property of persons within his jurisdiction. To accomplish these required functions, various State Police, Sheriff, and municipal police departments have been established.

State Police

As a general rule, State Police do not have investigative responsibilities for explosions in grain elevators. Within each State, the State Police are required by law to exercise primary police jurisdiction on all State routes, highways, and Federal routes and highways. In other areas, police jurisdiction is left to municipal or county police services. Where local resources are clearly insufficient to meet the requirements of an emergency or accident, the State Police will provide assistance. Usually this assistance consists of professional police services such as control of traffic (including access to/from affected locations), search and rescue, and communication services. Some State Police organizations also provide special criminal investigative services to local police jurisdictions for certain crimes such as murder investigations.

State Police investigated 1 of the 15 explosions. Their investigations were limited in scope and consisted of preliminary interviews of available witnesses at the scene. The reports documented State Police traffic control, rescue, and emergency transportation.

Sheriff-Local Police Departments

Certain authorities are required by law or by ordinance to have primary police responsibilities within defined jurisdictions. These authorities can include:

- (1) Chiefs of municipal police departments;
- (2) Town marshals for smaller municipalities; and
- (3) Sheriffs in unincorporated areas.

Assistance is rendered by county sheriffs to municipal police departments where resources are deemed insufficient. These services include enforcement of existing laws, ordinances, directives and regulations, maintenance of order, control of traffic, search and rescue, communications, and emergency transportation.

There are no specific guidelines provided to sheriffs and local police departments for investigating grain elevator explosions. The Task Force review found that local police or sheriffs prepared reports for five grain elevator explosions. Their investigations were limited in scope and consisted of preliminary interviews with available witnesses at the scene of the explosion. Their reports documented activities concerning traffic control, search and rescue, emergency transportation, and the preliminary identification of victims.

5.1.6. Other Investigations

Personnel from the EPA, FDA, and other agencies examined the circumstances surrounding a number of the 15 explosions. None made comprehensive investigations to establish causes because they were not responsible for investigating explosions in grain handling facilities. Their methods basically consisted of monitoring the investigative efforts of responsible agencies.

The insurance companies involved conducted investigations but the Task Force was not able to obtain these reports. In some cases this was because of pending litigation or because of company policy.

5.1.7. Conclusions

Based on the information in this section, the Task Force concludes that:

- Investigative agencies and authorities have not established the causes and circumstances for explosions in grain handling facilities because (1) some required investigations were not performed by responsible authorities, (2) some investigations were not completed, (3) some investigations were conducted without coordination among agencies, (4) some investigations were based solely on preliminary interviews of available witnesses or survivors, and (5) some investigations were performed by persons insufficiently trained in explosion investigation techniques.

- OSHA investigations are not specifically geared to identifying explosion causes. If these causes were known, the OSHA standards could be revised to increase safety in grain handling facilities.

5.1.8. Recommendations

Task Force recommendations include the following:

- Establish a responsible agency to coordinate the investigations of explosions in grain handling facilities.
- Require that all explosions and major fires in grain handling facilities be investigated and the results reported for analysis.
- Establish an interagency team of officials with specific expertise to make immediate investigations of all explosions and major fires in grain handling facilities. This team should provide both guidance and direction to facility operators and agencies responsible for enforcement of safety requirements.
- Develop and make available training in the techniques of explosion investigation as well as uniform guidelines and procedures for investigating explosions in grain handling facilities. These guidelines should set the minimum scope for investigations.

5.2. SAFETY, HEALTH, AND OTHER ENFORCEMENT

For many of the reasons detailed in chapter 2 and in this chapter, minimum requirements for dust control, housekeeping, electrical equipment, and control of welding and ignition sources remain voluntary guidelines. These voluntary guidelines have been developed primarily by the NFPA. Because these guidelines are voluntary they are not consistently enforced.

The Task Force surveyed enforcement efforts in the areas of safety and health, as well as environmental quality. This study reviewed applicable State laws, local codes, and inspection reports. The Task Force also conducted onsite interviews.

5.2.1. OSHA, U.S. Department of Labor

The purpose of the Occupational Safety and Health Act of 1970 (29 U.S.C. 651) is to assure safe and healthful working conditions for all American workers. To accomplish this OSHA is authorized to establish mandatory safety and health standards and to carry out an effective program of enforcement. The Act also established NIOSH which is responsible for research, experiments, and demonstrations relating to occupational safety and health. NIOSH also develops criteria for new and improved safety and health standards and recommends their adoption by OSHA.

General Industry Standards

Section 6(a) of the OSHA Act directs OSHA to promulgate safety and health standards from existing material, consensus standards, and established Federal standards. In 1971, OSHA promulgated its first Occupational Safety and Health Standards (29 CFR 1910). OSHA has effected periodic amendments to these standards.

At the present time OSHA has not adopted standards that are specifically designed for prevention of fires or explosions in the grain industry. OSHA's General Industry Standards are used currently to conduct inspections of grain handling facilities. These are summarized in appendix M. Most of these standards relate to personal safety hazards rather than the prevention of fire or explosion hazards. The personal safety requirements include standards addressing emergency escape exits, personal protective equipment, medical provisions, guards for machinery, and portable handtools.

OSHA has established health standards to limit worker exposure to dusts including grain dust. The permissible limit for grain dust is 15 milligrams per cubic meter and is substantially below known explosible concentrations. The exposure limit for grain dust is based on an 8-hour time weighted average. The explosible concentration for grain dust is significantly higher; it ranges from 20 to 55 grams per cubic meter.

OSHA does not use current codes for conducting inspections. For example, the 1971 National Electrical Code (ref. 26) was adopted by OSHA (29 CFR 1910.309) when its General Industry Standards were established. Although the code is revised every 3 years by the NFPA, OSHA still enforces the 1971 version. This technical code establishes design criteria for electrical systems in grain handling facilities in order to prevent fires and explosions.

Inspections of Workplaces

OSHA estimates that there are about 5 million workplaces covered by the Act and has established a system of inspection priorities as follows:

- **Imminent Danger:** Imminent danger situations are given top priority. These are conditions where dangers exist that can be expected to immediately cause death or serious physical harm before they can be eliminated.
- **Catastrophe and Fatal Accidents:** A high priority is given to investigations of catastrophes, fatalities, and accidents resulting in the hospitalization of five or more employees. These investigations are further discussed in section 5.1.1.

- **Valid Employee Complaints:** Third priority is given to valid employee complaints of alleged violations of standards or of unsafe or unhealthful working conditions. The inspections of complaints usually consist only of the items identified in the complaint. If the facility is relatively small, a complete walkaround inspection is made in conjunction with the complaint inspection.

- **General Inspections:** These inspections are scheduled as time permits. A complete walk-through inspection is normally performed.

Inspections are performed using this priority system. Citations may be issued for violations noted by OSHA inspectors. Depending on the nature of the citations, followup inspections are conducted to determine compliance with the established abatement time limits. The frequency of followup inspections is determined by the area office director after workload considerations are determined. The area director determines which citations are issued and the penalties to be imposed. The following are types of violations of OSHA standards and the appropriate penalties:

- **Imminent Danger:** This is a condition where a reasonable certainty of danger exists. The danger can be expected to cause death or serious physical harm immediately or before it can be eliminated through normal enforcement procedures. A penalty of up to \$10,000 for each violation may be assessed. If the violation caused the death of an employee the offense is punishable by a fine of not more than \$10,000 or by imprisonment for not more than 6 months or both.

- **Serious Violation:** This is a condition where there is substantial probability that death or serious physical harm could result and that the employer knew or should have known of the hazard. A penalty of up to \$1,000 is mandatory.

- **Nonserious Violation:** This is a condition that has a direct relationship to job safety and health but probably would not cause death or serious physical harm. A penalty of up to \$1,000 is optional.

- **De minimis:** A violation that has no direct or immediate relationship to job safety and health. A warning notice is issued but citations are not.

Review of available OSHA inspection reports and interviews with responsible OSHA field personnel disclosed that half of the facilities were inspected prior to the explosions. Of those inspected, four were general inspections and four were complaint inspections. All were cited for violations of either OSHA standards or the General Duty Clause, section 5(a)(1) of the Act. Fol-

lowup inspections were made at five of the eight inspected facilities.

Violations of General Duty Clause

OSHA's primary concern in performing an inspection is to determine whether an employer is complying with safety and health standards promulgated under the Act. OSHA must also determine if an employer is also complying with the General Duty Clause.

The General Duty Clause stipulates that an employer must provide a workplace free from recognized hazards. If OSHA standards are unavailable, consensus standards are used as the basis for violations and for subsequent OSHA citations. Hazardous conditions which apparently violate OSHA standards or the General Duty Clause are cited as violations only when it can be shown that an employee was actually exposed to, or potentially exposed to, the hazardous conditions.

Under OSHA guidelines a condition constitutes a recognized hazard when it is common knowledge or generally accepted as a hazard in the particular industry. It must be detectable by means of the senses.

To support General Duty Clause citations, OSHA uses nationally recognized consensus standards. The NFPA's Standard 61-B, 1973, "Grain Elevators and Bulk Grain Handling Facilities" is one of the standards used for grain elevators. The NFPA's Standard 61-B covers such subjects as structural features, ventilation, explosion relief, equipment, dust control, housekeeping, and safeguards to prevent ignition. Additional NFPA Standards referenced in NFPA No. 61-B are listed in appendix P. Because these standards are intended only as guidelines compliance with them is voluntary. Within the industry disagreement exists over what constitutes a recognized hazard. This lack of agreement results in difficulties and inconsistencies in OSHA's enforcement of these consensus standards.

On May 5, 1978, OSHA issued a memorandum to its employees establishing guidelines for inspections of grain elevators (appendix N). These guidelines require that elevators be cited under the General Duty Clause for violations which are failures to apply recognized preventive measures (lack of motion switches, elevator leg venting, methods for removing tramp metal, or loose or broken elevator buckets, etc.). However, the absence of other recommended preventive measures was not addressed because they are not now universally recognized as hazards.

Recent Inspections

Stimulated by the explosions that occurred in December 1977, OSHA placed more emphasis on grain handling inspections. From its inception through the end of 1977 OSHA conducted 1,858 initial inspections and 496 followup inspections in facilities primarily engaged in the storing and milling of grain. During the 6-month period from December 1977 through May 1978 OSHA conducted 798 initial and followup inspections in these facilities. During the period December 1, 1976, through November 30, 1977, OSHA conducted 382 inspections.

OSHA also established a training program to better acquaint its compliance officers with requirements for proper inspection techniques in grain handling facilities. The training program consisted of lectures and a prepared instructional film. The film was presented at each OSHA area office. In order to highlight hazards in grain handling facilities OSHA issued a grain elevator hazard alert to elevator operators.

OSHA officials advised that the program was initiated to train compliance officers for grain handling facility inspections. They acknowledged that in the past compliance officers conducted inspections of these facilities without sufficient knowledge of elevator operations. They said compliance officers had difficulty establishing the proper classifications of facility areas for determining compliance with the National Electrical Code hazard requirements, and recognizing hazards under the General Duty Clause, section 5(a)(1).

5.2.2. NIOSH, U.S. Department of Health, Education, and Welfare

NIOSH is the principal Federal agency engaged in research in the national effort to eliminate on-the-job safety and health hazards. It was established within HEW under the provisions of Public Law 91-586, the Occupational Safety and Health Act of 1970. NIOSH conducts research and develops criteria on which new standards can be based. NIOSH funds and operates education and training programs to alleviate the shortage of trained occupational safety and health personnel.

The NIOSH mandate comes from four Congressional Acts:

1. The Federal Coal Mine Health and Safety Act of 1969.
2. The Occupational Safety and Health Act of 1970.
3. The Toxic Substances Control Act of 1976.
4. The Mine Safety and Health Act of 1977.

Although primarily a research agency, NIOSH is required by law to testify at public hearings in support of safety and health standards and to provide technical assistance to both labor and management. NIOSH recommends safety and health standards to the Department of Labor for promulgation and enforcement. NIOSH is also responsible for making accident prevention recommendations for all workplaces in which oxidizable dusts are a problem.

NIOSH's Division of Safety Research currently performs the following functions:

- Serves as the focal point for occupational safety research programs,
- Designs and conducts safety research aimed at preventing or mitigating injury to workers in all industries,
- Conducts accident investigations and provides technical consultation relating to safety problems in all industries,
- Develops criteria for recommended safety standards,
- Develops regulations for certification of personal protective devices, industrial hazard measuring devices and quality control programs, and
- Tests and certifies personal protective devices and occupational hazard measuring devices.

5.2.3. FDA, U.S. Department of Health, Education, and Welfare

The FDA was established by the Federal Food, Drug, and Cosmetic Act (21 U.S.C. 301). The purpose of this agency is to prevent the contamination of basic food materials with filth and/or other contaminants.

FDA enters into two kinds of agreements with States. The first, worksharing agreements, apportion workloads and expenses between the State and the Federal agency. The second, cooperative agreements, primarily concerns performance of necessary inspections and investigations to enforce provisions of the Act. Both types are currently in effect.

Normally, inspections of facilities are conducted as the result of complaints. There are no requirements which state the frequency with which these inspections must be performed. The scope of these inspections includes all types of food grains for consumption by humans and animals.

FDA officials advised the Task Force that during a recent 12-month period responsible State agencies conducted 2,291 inspections of grain mills and

feed processors and 690 inspections of grain elevators. They said that FDA performed 616 inspections of grain mills and feed processors and 200 to 300 inspections of grain elevators during the same period. The FDA is usually requested to conduct inspections of grain handling facilities that have exploded. The purpose of these inspections is to determine whether salvaged grain has been contaminated as a result of the explosion.

5.2.4. U.S. Coast Guard, U.S. Department of Transportation

The Commandant of the U.S. Coast Guard is authorized to prescribe such conditions and restrictions relating to the safety of waterfront facilities and vessels in ports as he deems necessary. These can include inspection, operation, maintenance, guarding, and manning of fire protection measures for vessels and waterfront facilities. Local Coast Guard officials at explosion sites said that there is no established frequency for conducting inspections of waterfront facilities, including grain elevators. Normally, inspections are not made within facilities, but are limited to facility wharf areas.

5.2.5. Fire Authorities

As mentioned in section 5.1.4., most local fire authorities are supervised by a State Fire Marshal. The Fire Marshal is responsible for establishing training programs for fire prevention and inspection. In most cases these responsibilities have been delegated to fire authorities in municipalities. In those States having no State Fire Marshal, the different localities are responsible for conducting their own training and required preventive inspections.

Normally, the chief of a municipal fire department or chief fire officer of each special fire district is required to make fire prevention inspections within their respective jurisdictions. The State Fire Marshal conducts inspections in unincorporated areas.

All inspections are conducted according to State laws and regulations established by the State Fire Marshal. Inspections can also be conducted according to nationally recognized building and/or fire prevention codes. Each municipality can also enforce its own ordinances. Usually State laws and regulations address requirements for proper exits, other means of egress, exit signs, exit ramps, fire extinguishers, fire alarms, etc. Other requirements may be enforced including various national consensus building codes and individual fire protection

codes. The codes for most inspection purposes are not current.

Generally Fire Marshals are required by State statutes to inspect or have inspected under their supervision:

- Hotels, motels, lodging houses, and apartment buildings
- Educational facilities, including day care
- Theatres and dry cleaning establishments
- Places of assembly
- Flammable liquid installations
- Gas pipeline installations and,
- Hospitals and nursing homes.

State fire personnel said that it is not possible to perform all required inspections because of staff limitations. Schedules are established to give priority to the oldest buildings such as hotels, motels, and theatres, followed by requests from individuals.

None of the 15 selected grain elevator facilities had been inspected by responsible State Fire Marshals prior to the explosions. The State Fire Marshals interviewed by the Task Force said they had delegated responsibilities for inspection of these facilities to local fire authorities.

5.2.6. Local Fire Departments

Local fire departments can be classified into three groups: volunteer fire departments, paid mutual aid societies, and paid fire departments.

Interviews with fire officials responsible for the 15 grain elevators disclosed that the paid fire departments usually conducted periodic inspections of establishments within their jurisdictions. The Task Force was told that paid fire department personnel received formalized training in conducting fire prevention inspections and fighting fires.

The Task Force learned that volunteer fire department personnel received little training concerning fire prevention inspections and fighting fires. All of the volunteer firemen interviewed by the Task Force said that they had received no training for fighting fires resulting from a dust explosion. The volunteer firemen also said that they sometimes made formal inspections of establishments within their jurisdictions, but usually they conducted onsite visits to familiarize themselves with the facilities.

Eight of the 15 grain handling facilities that exploded were provided fire protection by paid fire departments. Six were provided protection by volunteer departments and one was provided fire protection by a mutual aid society.

Inspection reports showed that 6 of the 15 grain handling facilities had not been inspected by responsible fire authorities. Of the remaining facilities six had been inspected 7 to 12 months before the explosions and three had been inspected 6 months before the explosions. Three of the nine inspections were conducted by volunteer fire departments and six of the inspections were conducted by paid fire departments. An analysis of the available inspection reports disclosed that the scope of the inspections varied from an onsite walk through to evaluation of facilities to determine compliance with municipal codes.

5.2.7. Building Authorities

In each of the States surveyed many agencies were responsible for establishing minimum building standards for public and private structures including grain elevators. Normally a State building commission is required by law to enforce a state building code. This gives them overall responsibility for the State. These commissions are also responsible for approving design, construction, repair and maintenance of state-owned buildings. In some States, county and/or city governments independently may enact ordinances or resolutions to establish minimum codes and specifications for the design, construction, repair and maintenance of public and private structures within their jurisdictions.

These codes and specifications are promulgated by the particular jurisdictions from available nationally recognized building and fire prevention codes. Although many of the codes provide overlapping coverage, some only address particular industries, buildings, equipment, or practices. Enforcement criteria change frequently because the codes on which they are based are often revised.

New construction, renovation, or modification usually requires a permit from the responsible local authority. These permits are issued at the municipal level for incorporated areas and county level for unincorporated areas. State laws frequently require permits for construction or installation of facility equipment such as pollution control equipment. Work done under the authority of a permit is normally inspected during construction. Contractors must be approved and obtain permits. Inspections normally are limited in scope and generally do not include a followup.

5.2.8. Office of Air and Waste Management U.S. Environmental Protection Agency

The grain industry and others have alleged that Federal, State, and local air quality regulations have increased the potential for dust explosions in handling facilities. These regulations do not require that any dust be contained within grain handling facilities. The following is an overview of EPA responsibilities regarding grain handling facilities.

As required by the Clean Air Act the EPA establishes national standards for overall air quality. These standards specify allowable pollutant levels and are designed to protect public health and welfare. The Federal Air Quality Standards for particulate matter which include grain dust were adopted in 1971. Each State is required to adopt rules to limit pollution from specific sources to meet these general air quality standards. Each State determines the level of enforcement and the sources to be regulated. Requirements must be sufficient to achieve the Federal Air Quality Standards. States submit program plans to EPA for approval and EPA reviews the plans to assure that the Federal Air Quality Standards are met.

Many States had air quality standards prior to the Clean Air Act. State and local regulations vary in type based on the need to achieve Federal Air Quality Standards and other State and local objectives. Many of these regulations are not written expressly for grain elevators.

There are two different types of regulations for limiting emissions. The most commonly enforced State and local regulations are those that base the emission limit on the quantity of grain handled by each facility. This limit is called the process weight limitations. Other States regulate based on limitations of visible emissions of grain dust. Regulations for highly populated areas are usually the most stringent.

The areas and operations in grain handling facilities normally affected by these regulations are those with visible emissions. This may include areas such as truck loading and unloading, railcar loading and unloading, barge unloading, ship and barge loading, and transfer points throughout the facilities.

On August 3, 1978, EPA implemented the first Federal Air Quality Standards for grain handling facilities. The new rules cover only new, modified, or reconstructed elevators that have a grain storage capacity greater than 2.5 million bushels or processing facilities and mills with permanent grain storage capacity of more than 1 million bushels. EPA estimated that only about 500 facilities would

be subject to these regulations. The Standards limit the amount of grain dust emissions from nine specific points in these facilities as follows:

- **Truck Loading Station:** Visible emissions, those seen by the naked eye, are not to exceed 10 percent opacity (the degree of obscuration of light—zero percent opacity is completely clean, while 100 percent opacity is totally dark).
- **Truck Unloading Station, Railcar Loading Station, Railcar Unloading Station:** Visible emissions must not exceed 5 percent opacity.
- **Ship or Barge Loading Station:** Visible emissions are not to exceed 20 percent opacity.
- **Ship or Barge Unloading Station:** Equipment specified in the regulations must be used.
- **Grain Drier:** Visible emissions are not to exceed zero percent opacity.
- **All Grain Handling Operations:** Visible emissions must not exceed zero percent opacity.
- **Emission Control Devices:** Visible emissions are not to exceed zero percent opacity and the particulate concentration in the exhaust gas discharge into the atmosphere should not exceed 0.023 grams per cubic meter of air.

Review of available material and interviews with responsible officials disclosed that present air pollution control rules do not require the accumulation of dust inside elevators. Further, EPA officials advised that compliance with present air pollution control standards includes the collection and removal of dust from the elevator. These methods of compliance are also recommended by insurance companies and the NFPA.

5.2.9. Other Enforcement

Operators for the 15 surveyed facilities disclosed that their insurers normally inspect facilities on a regular basis. They said the frequency depends on previous inspections and experience. Inspections of entire facilities are made on an annual or semiannual basis. In addition, insurers require facilities to conduct weekly or monthly fire prevention inspections and submit written reports of their findings. The scope of these inspections is frequently to check or test available fire fighting equipment and conduct a complete facility walkaround.

Five of the 15 grain handling facilities had been inspected by the insurers within 6 months of the explosions. Ten of the facilities were inspected within 12 months of the explosion.

5.2.10. Conclusions

The Task Force concludes the following:

- Industry consensus standards for dust fire/explosion preventive measures have been established. Compliance with these consensus standards is voluntary. As a result, these measures have been applied inconsistently by the grain handling and processing industries.
- OSHA has not established standards that are specifically designed to prevent fires and explosions in grain handling facilities. Present OSHA standards relate to personal hazards rather than the prevention of dust fires and explosions.
- While OSHA employee exposure limits for respirable dust appear to be adequate in the context of worker health, the enforcement of these standards is only peripherally related to explosion hazards and safety. These health standards address dust concentrations over a period of time while explosion and fire hazards are contingent upon instantaneous airborne dust concentrations.
- OSHA has not adopted current revisions of the National Electrical Code and therefore only enforces the older standards.
- There is a lack of agreement concerning what constitutes a hazardous condition in a grain handling facility. Consensus standards are not universally accepted as such.
- OSHA places considerable reliance on the use of its General Duty Clause in enforcement inspections of grain handling facilities. Use of voluntary consensus standards to support OSHA General Duty Clause citations has resulted in confusing and inconsistent application.
- OSHA has increased its inspections of grain handling facilities. It has also provided additional training to better acquaint its personnel with facility operations and hazards.
- Although the U.S. Coast Guard can inspect, operate, maintain, guard, and man fire protection measures for waterfront grain handling facilities, this is not required nor is the frequency specified.
- Referenced consensus standards or codes in States and/or local statutes are not promptly revised to permit enforcement of current standards or other requirements.
- Grain handling facilities have been constructed according to various national consensus building codes and individual fire protection codes. Minimum codes and specifications vary and frequently do not specify requirements for grain handling facilities.

- Fire prevention inspections are conducted according to various national consensus fire prevention standards and local codes. As a result the comprehensiveness of these inspections varies widely.

- Fire prevention inspections of grain handling facilities are frequently performed by inadequately trained personnel.

- Fire prevention inspections by responsible authorities are not always conducted on a regular basis.

5.2.11. Recommendations

The Task Force recommends the following:

- Develop and establish better coordination among industry, government, and professional organizations in the development of consensus standards for grain handling facilities.

- Study and determine the effectiveness of such industry consensus standards in preventing dust fires, explosions and other hazards in grain handling facilities.

- Adopt appropriate industry consensus standards and uniformly enforce them as well as Federal and other regulations.

5.3. EMERGENCY PREPAREDNESS

Each State is subject to natural and manmade disasters including hurricanes, tornadoes, storms, floods, high water, wind-driven water, tidal waves, earthquakes, landslides, mud slides, snowstorms, droughts, fires, explosions, and other catastrophes. They cause injury, death, damage to property, and economic loss to local communities, States, and the Federal Government. The disaster response capability of local governments often must be reinforced by State and Federal resources or by mutual support agreements with adjoining political subdivisions.

All States and their political subdivisions maintain a variety of governmental and volunteer emergency services. These organizations provide manpower, facilities, and equipment, and normally are adequate to cope with day-to-day emergencies such as transportation accidents, dwelling fires, etc. Their response capabilities are often exceeded by the demands resulting from major disasters or emergencies such as severe floods, large industrial explosions, etc. Adequate response, therefore, must rely on plans and programs which permit the rapid mobilization and coordinated utilization of available resources of local, State, and

Federal governments and of private citizens. These resources include personnel, equipment, supplies, physical facilities, and financial assistance.

When a disaster occurs emergency operations are usually initiated by the lowest level of government affected. Municipalities and counties or similar governmental subdivisions are the first sources of governmental assistance. The State government is responsible for emergency response on property owned or controlled by the State and provides assistance to smaller jurisdictions. The Federal Government is responsible for federally owned or controlled properties and provides assistance to the State.

Recognizing that the principal purpose of all disaster preparation is to alleviate the suffering and damage which result from disasters, Federal legislation has placed primary responsibility for disaster preparedness and response with each State. Under existing laws the Federal Government uses grants to encourage the development of comprehensive disaster preparedness and assistance plans, programs, capabilities, and organizations. These laws provide direct Federal assistance to compensate for both public and private losses. The major laws enacted by the Federal Government in this area are as follows:

1. The Federal Civil Defense Act of 1950, as Amended (Public Law 21-630).
2. The Disaster Relief Act of 1970, as Amended (Public Law 91-601).
3. The Disaster Relief Act of 1974, as Amended (Public Law 93-233).

Individual States have adopted compatible statutes to implement the requirements of these laws and/or eliminate conflict with them.

Implementation of these Acts has created two separate Federal agencies with interrelated responsibilities for disaster preparedness and response. A discussion of each agency follows.

5.3.1. Defense Civil Preparedness Agency

The DCPA is an agency within the Department of Defense. Its mission is to discharge the civil defense functions prescribed by the President by providing a national program to minimize the effects of an enemy attack. The responsibility for implementing a national civil defense program is vested primarily in the States and their political subdivisions. The State and local civil defense

organizational structures provide relief and assistance in areas of the United States struck by other disasters in addition to enemy attack.

The DCPA through other Federal agencies, State, and local authorities is responsible for providing guidance and coordination for the development and implementation of:

- A shelter program including evacuation and movement to shelter;
- A radiological fallout warfare defense program;
- Steps to warn the U.S. population of an enemy attack;
- Civil defense communications, including an appropriate warning network and radiological monitor reporting capability;
- Emergency assistance to State and local governments in a post attack period;
- Protection and emergency operational capability of State and local government agencies to provide continuity of government;
- Programs for making financial contributions to the State for civil defense purposes;
- Plans and the operation of systems to undertake a nationwide post attack assessment of the nature and extent of the damage resulting from enemy attack and the surviving resources;
- Use of a civil defense communications system for warning the affected population of impending natural disasters;
- Planning assistance to State and local governments in connection with adaptation and use of preparedness plans and capabilities for other than enemy caused disasters; and
- Supporting programs including training and education, research and development, emergency public information, participation by industry and national organizations, and foreign civil defense liaison.

In order to provide for the development and implementation of these activities the DCPA provides funds to each State to cover personnel and administrative expenses. To be eligible for DCPA financial assistance each State must submit a State Administrative Plan for approval. These plans describe the State civil defense program and related administrative plans and procedures.

The DCPA presently does not require that States resubmit their State Administrative Plans for review. Instead, each State is required to submit proposed changes for approval before incorporating them into their plans. These changes

are to be made as necessary and should reflect the current status of the administration of the state's civil defense activities.

The DCPA and its attendant State and local preparedness organizations have responsibilities which include the relief of suffering and damage in the event of disasters. Severe explosions in grain handling facilities are not addressed specifically. The relationship between the DCPA and specific localized disasters such as elevator explosions is remote. The functions of this agency are often combined with those of FDAA which is an agency of HUD.

5.3.2. Federal Disaster Assistance Administration

The FDAA is responsible for providing the following:

- Federal assistance for public and private losses and needs sustained because of disasters;
- Encouraging the development of comprehensive disaster preparedness and assistance plans, programs, capabilities, and organizations by States and local governments;
- Achieving greater coordination and responsiveness of disaster preparedness and relief programs;
- Encouraging individuals, States, and local governments to protect themselves by obtaining insurance coverage to supplement or replace governmental assistance; and
- Encouraging hazard mitigation measures and environmental planning including development of land use and construction regulations to reduce losses from disasters.

As provided for by the Disaster Relief Act of 1974, each State initially applies for a \$250,000 development grant. Grant funds are to be used to develop plans, programs, and capabilities for disaster preparedness and prevention. After individual plans have been approved, the States are eligible for an annual \$25,000 grant for improving, maintaining, and updating disaster assistance plans. In their applications for the initial development grants the States were required to:

- Include a State work plan that sets forth a comprehensive and detailed program of work to develop adequate capability for prevention of and to provide assistance following emergencies and

major disasters, including provisions for assistance to individuals, businesses, and local governments;

- Indicate the designated State agency or agencies that would be involved in the development effort and the State disaster preparedness coordinator appointed by the Governor;

- Include provisions for appointment and training of appropriate staffs, formulation of necessary regulations and procedures, and performance of required exercises to ensure that the plans, programs, and capabilities can be implemented; and

- Describe the relationship of the proposed work with other disaster related plans, programs, and capabilities.

Each State was also required to develop and submit for approval a State Emergency Plan that included:

- The kinds of disasters to which the State is most vulnerable and the particular requirements for disaster response; and

- Provisions for state guidance and assistance to local authorities to develop their disaster preparedness plans, programs, and capabilities.

The development grant could be used by the States to develop other preparedness programs and capabilities such as:

- Planning for disaster response in general, for specific disaster contingencies in specific locations, for local area mutual emergency support under State sponsorship, and for disaster alleviation and hazard reduction;

- Revision, as necessary, of State legislation implementing orders, regulations, and other authorizations and assignments relevant to disaster preparedness and assistance;

- Developing disaster-related interstate mutual aid compacts and agreements;

- Conducting vulnerability analyses not otherwise available but necessary for the development of State and local disaster preparedness plans and programs;

- Designing disaster-related emergency systems;

- Training and exercises;

- Program reviews and post-disaster analyses; and

- Public information and education programs.

5.3.3. State Preparedness

Each State has established a State Department of Civil Defense and Emergency Preparedness for the purpose of coordinating all State disaster

plans and responding to nuclear, manmade, and natural disasters. The responsibilities and guidelines established by the DCPA and FDAA have been consolidated in State governments. A director appointed by the Governor maintains facilities that provide readiness to implement emergency operations during a disaster.

The State Disaster Preparedness Plans identify and assign responsibilities for States and for their local governments. These plans enable response to the threat or occurrence of any disaster, including nuclear attack, within each State. The plans also detail the coordination required for Federal assistance following presidentially declared emergencies or major disasters.

The plans describe the functions that must be performed during predisaster, immediate response, and short-range recovery from a disaster. The division of responsibility among the different levels of government is described for each of the following functions:

- Direction and control
- Warning
- Search and rescue
- Emergency medical assistance
- Identification and mortuary services
- Evacuation
- Emergency communications
- Public information
- Reporting
- Traffic control
- Debris clearance
- Damage survey and assessment
- Public health and sanitation
- Temporary housing and shelter
- Mass care and feeding
- Fire fighting.

The functions further showed primary and support responsibilities for each government level. They identified the general nature and type of state resources necessary to accomplish each disaster function. The descriptions further outlined the procedures to be followed by the local governments in obtaining assistance.

These State plans also described the nature and extent of Federal disaster assistance available as a result of presidentially declared emergencies and major disasters, the procedures for obtaining a presidential declaration and assistance, and the requirements for coordination with the Federal

Government to respond to the needs of disaster victims.

5.3.4. Local Preparedness

The Task Force interviewed the responsible officials and analyzed the established emergency preparedness plans for a parish and a municipality. Each had experienced a serious grain elevator explosion. One had a disaster response problem and the other seemed to have none.

The principal executive officers of local jurisdictions appoint directors to their respective Departments of Civil Defense and Emergency Preparedness. Each Department maintains facilities to implement emergency operations during a disaster. This pattern was followed in the two cases analyzed.

The local Disaster Preparedness Plan for the parish government was prepared solely under guidelines provided by the DCPA. It was intended for response to a nuclear attack. The plan identified and assigned responsibilities for actions by the parish and its municipalities to respond to the threat or occurrence of nuclear attack. The plan described the functions to be performed during preattack, immediate response, and short-range recovery. The division of responsibility among the different levels of parish government were delineated for each of the following functions:

- Direction and control
- Communications
- Increased readiness
- Shelter
- Warning
- Radiological defense
- Fire
- Rescue
- Public works and engineering.

The parish emergency preparedness plan did not describe the state role or its response procedures. The plan did not outline parish procedures for obtaining assistance or handling requests from municipalities within its jurisdiction.

The parish Civil Defense Director states that individual disaster preparedness plans for other disasters such as hurricanes, transportation accidents, explosions, fires, severe weather, etc., had not been completed. He did advise that the present plan could be utilized for disasters other than nuclear attack.

The local Disaster Preparedness Plan for the municipal government was originally prepared under guidelines provided by the DCPA. The plan was updated in 1977 and includes provisions for natural or manmade disasters. The plan identified and assigned responsibilities for a response to the threat or occurrence of disasters including nuclear attack. The plan described the functions that must be performed during predisaster, immediate response, and short-range recovery. The division of responsibility among the different levels of municipal government were described for each of the following functions:

- Direction and control
- Security
- Fire control
- Communications
- Warning
- Emergency medical services
- Emergency medical transportation
- Search and rescue
- Evacuation.

The municipal emergency preparedness plan did not describe the State and county response procedures to the threat or occurrence of a disaster. The plan did not outline procedures to be followed by the municipality in obtaining assistance from the county.

In order for either the municipal or parish plans to be activated in the event of a disaster the principal executive officer had to declare an emergency. This declaration would activate the response and recovery aspects of these local plans and authorize aid and assistance. This declaration is required before assistance can be requested from the next higher level of government.

Both Civil Defense Directors advised that their disaster plans had not been activated as a result of the grain elevator explosions that occurred within their jurisdictions in 1977. The reason for the lack of action in both cases was that the responsible principal executive officers did not declare a state of emergency. Local facilities and personnel, however, were activated on a standby basis. The parish Civil Defense Department provided personnel and equipment to assist in communications and in search and rescue operations. The municipal Civil Defense Department did not provide any direct assistance to the other responding municipal departments and organizations.

The assistance provided by local authorities in connection with the grain elevator explosion occurring within the jurisdiction of the parish was neither efficient nor coordinated. For example, the parish sheriff usurped the authority of the responsible fire chief to control the explosion scene. As a result, some of the responding fire personnel and equipment were denied access to the scene. The explosion severed available water hydrant lines so hose relays had to be formed to bring water from a nearby river. The responding firemen were not properly trained in preparing these required relays and so the water could not be applied until about 2 hours after the explosion occurred.

No specific problems concerning lack of assistance or aid were disclosed for the explosion that occurred within the jurisdiction of the municipality. Local authorities advised that they were satisfied with the responses provided by their respective departments.

5.3.5. Conclusions

Based on the study of emergency preparedness plans and the interviews of responsible officials at each governmental level, the Task Force concludes the following:

- Two separate Federal agencies provide direction, guidance, funding and other assistance for emergency preparedness to the States but overlapping and conflicting responsibilities result.
- State direction, guidance, funding and other assistance to the county and municipal levels appears to be inadequate.

- Emergency planning at the State, county, and municipal levels is oriented toward civil defense and natural disasters rather than major industrial catastrophes.

- The principal executive officers at the lowest governmental levels are charged with the responsibility for declaring a local emergency. Executive officers do not consider explosions in grain handling facilities as disasters and have not activated local emergency preparedness plans.

- Local emergency preparedness plans or the ability to effect such plans will vary from one jurisdiction to another and as a consequence emergency services range from completely adequate to less than sufficient.

- Grain handling facilities cannot depend on local authorities to act consistently in an efficient and timely manner when a disaster occurs.

5.3.6. Recommendations

Task Force recommendations are as follows:

- Develop and implement formal emergency preparedness plans for each grain handling facility. Such plans should be developed in direct coordination and agreement with the appropriate local authorities.
- Train all personnel employed in grain handling facilities in the appropriate response procedures as outlined in facility emergency preparedness plans.

Chapter 6

RESEARCH AND TECHNOLOGY TRANSFER

Research and its application represents a significant part of any solution to the problems of fires and explosions in grain handling facilities. This chapter presents the current status of research efforts and technology transfer.

Conclusions and recommendations for this entire chapter are combined in sections 6.4 and 6.5.

6.1. INTERNATIONAL SYMPOSIUM ON GRAIN ELEVATOR EXPLOSIONS

The USDA sponsored an International Symposium on Grain Elevator Explosions in Washington, D.C., on July 11 and 12, 1978, under the direction of the NMAB of the NAS. Its purpose was to develop a mechanism for generating a current statement of informed opinion regarding both the causes of fires and explosions in grain handling facilities and viable means of prevention.

Within this format a broad picture of world experience developed. Symposium participants included domestic and foreign researchers, representatives of the grain industry, the insurance industry, dust collection system manufacturers, organized labor, and representatives of both the United States and foreign governments.

Recognized authorities in many fields addressed the problem of safety in grain handling facilities from many different perspectives. Presentations dealt with aspects of explosion phenomena as well as the problems of grain elevator safety as they affect other groups involved in handling grain.

Material submitted by participants was published as a preprint by the NAS. In addition 34 formal presentations were delivered orally during the Symposium. Eight presentations were from representatives of foreign countries. Discussion followed each presentation and a general discussion occurred upon completion of all presentations. This other material was published as a volume of proceedings.

The Symposium succeeded both in presenting new data regarding improved grain handling practices and in shaking the foundations of some long-held beliefs.

6.1.1. Major Points

In their abstract of the proceedings (ref. 27) NAS listed the following items as the principal opinions evolving from the Symposium.

- There exists much fundamental dust explosion information which is not yet being applied to the problems in grain handling facilities.
- U.S. grain elevators could be cleaner than they are.
- Regularly scheduled preventive equipment maintenance is needed.
- Facility operator and employee training in safe practices regarding fire and explosion prevention needs constant effort.
- Through appropriate rating structures designed to eliminate elevator conditions causing or contributing to fires and explosions, the insurance industry can significantly affect grain handling safety.
- While not ruled out, meteorological effects on explosion hazards are questionable.
- The probability of having primary ignition sources should be accepted and the dust problem attacked first.
- The practice of reintroducing already separated dust into the grain stream should be discontinued in U.S. elevators.
- Improved elevator design could decrease explosion losses by minimizing the propagation of an explosion from one part of an elevator to another.
- U.S. grain elevators could be safer if their designs incorporated better explosion relief venting as well as other recognized methods for alleviating the effects of explosions.

6.1.2. Other Important Points

Differences of opinion did develop but generally these were limited to different approaches to solving the problems of grain elevator safety rather than any disagreement on fundamental technical concepts.

In addition to the principal opinions, the following opinions expressed during the Symposium also have merit and should be considered carefully.

Dust Control

- Mechanical dust control systems which are installed in grain handling facilities must be capable of maintaining negative pressure in all enclosed components of the system.
- Installation of dust control systems should require prior approval by an engineer certified in dust control design.
- Licensing should be required of dust control equipment installers.
- Mandatory, regular inspections of dust control system performance should be required.
- Designers and installers of dust control systems should be required to prepare and issue written and verbal instructions concerning operation and maintenance of their equipment.
- Dust control systems must be designed with maximum automatic features to minimize human errors.
- Mandatory daily readings and recordings of pressure differential gauges of filter collectors must be required.
- Manometers must be clearly and permanently labeled with written instructions regarding efficient system operation.
- Facility operations should be halted when any part of the dust control system becomes dysfunctional.
- Collected dust should be stored outside of the elevator buildings.

Safety Instrumentation and Equipment

- Accepted bonding and grounding techniques should be used in conjunction with all moving equipment, especially belting.
- Heat detectors should be installed on all main bearings and motor housings.
- Magnetic, gravity, or pneumatic separators should be installed between receiving dumps and elevator legs.

- Inerting might be effective if used on elevator legs.
- Sectional suppression barriers should be installed in elevator legs.
- Continuous monitoring and early warning systems should be installed in handling facilities. Systems should include dust concentration monitors, sensors for humidity, moisture content and temperature, detectors for combustion gases, belt slowdown, bin hotspots, and voltage buildup.
- Explosion control systems, such as inerting, containment, relief venting, and suppression should be adopted.

Maintenance

- Grain handling facilities should be required to develop and implement operational and preventive maintenance systems.
- Preventive and reaction measures should be adopted for slipping head pulleys.
- A system of routine checking and preventive maintenance must be established for determining conditions of all buckets on elevator legs.
- Electrical equipment throughout the facility must be required to comply with the latest National Electrical Code.
- No hot work and particularly no welding should be allowed in a facility while operating.
- Welding permits must be required for both company and contract employees.
- Conveyors and elevator legs should be completely dust-tight.
- Intervents should be used on bulk weighing hoppers and similar equipment where grain is discharged in surges.
- Spouting runs should be kept as short as possible to reduce dust emissions.
- Dead boxes should be used on long spouting runs to reduce dust emissions.
- Facilities should halt operations at least once a day to allow for preventive maintenance.
- Conveyor belts should be designed for reduced dust generation by incorporating lower speeds with increased size, thus allowing a deeper bed of grain on the belt.
- Plastic leg buckets should be used more extensively.
- All maintenance programs should include mandatory recordkeeping provisions.
- Belts made of nonflammable materials should be used extensively.

Housekeeping

- Housekeeping programs must be developed and rigorously implemented.
- Vacuum cleaning systems instead of the hazardous practice of blowing down with compressed air should be used where possible.
- All facility operations must be halted during and immediately following housekeeping blow-down.

Facility Design and Construction

- New facilities must be designed with all possible explosion protection including explosion relief venting and isolation of hazard areas.
- Headhouse type construction should be eliminated in all new facilities.
- New facilities or the retrofitting of old facilities should locate elevator legs on the outside of the buildings.
- Suppression barriers should be installed in all aspiration or dust extraction lines.
- Grain inspection laboratories, control rooms, offices, and lunchrooms must be located a safe distance from the facilities.
- New elevators should be designed to reduce the number of points where dust can accumulate.

Management-Employee Responsibilities

- Facilities must be regularly checked for the presence of possible ignition sources and other possible explosion hazards. This procedure and appropriate reactions to hazards must be systematized and made an integral part of facility operation.
- The development and implementation of emergency preparedness plans must be required.
- Elevators should be required to provide hazard recognition and safety training for all employees.
- Safety meetings must be held regularly.
- There should be no smoking in any grain elevator. This policy should be strictly enforced. If smoking is permitted it must be confined to designated safe areas.
- Quantitative standards to gauge the effectiveness of housekeeping in reducing suspended dust and static dust accumulations must be developed and implemented.
- Established standards for explosion relief venting must be applied more stringently.
- Established standards for elevator equipment must be applied more stringently.

Other

- Explosion research teams with expertise in all phases of grain, grain handling, grain facilities, grain equipment, and safety should be organized to assist owners and operators in achieving and maintaining safe facilities.
- A national information center should be established to better achieve necessary levels of technology transfer.

6.2. RESEARCH OVERVIEW

Applied and theoretical research regarding fires and explosions in grain handling facilities has been conducted since 1900. Much of the research has been independent and this has resulted in duplication of effort, overlapping projects, and omission of basic studies. Present researchers have not found solutions to the explosion problem in spite of the considerable knowledge available.

Recently there has been a surge in the research effort. Federal and State governments have increased research and funding. At least nine universities are currently doing research on grain dust. Many organizations and institutions are researching grain dust explosions and other related areas. Proposals seem to be more numerous than ever. The chances for unraveling the mysteries of the explosion phenomena and for obtaining viable solutions to the problem of grain dust fires and explosions are extremely encouraging.

Coordination of research efforts is essential. The size and complexity of the grain handling and processing industries, coupled with the growing number of researchers and other actors involved, demands coordination, guidance, and leadership. There is a pressing need to find a means of collecting and disseminating the results of research and historical analysis.

Time is crucial. The need for applied technology requires centralized and effective collection, organization, and distribution of available research results. This effort should not be overlooked for, although future research projects are important, their possible benefits do not affect the present situation.

In a continuing effort to improve conditions in the grain industry the USDA's Special Coordinator for Grain Elevator Safety and Security directs and coordinates Departmental activity in this area. Special emphasis is placed on developing and implementing new research projects. As detailed in chapter 2, the USDA could provide a focal point and a leadership role for others involved in solving this problem. In part, this has

already been accomplished by the Special Coordinator.

Although past research is well-documented, current research proposals and projects are monitored inadequately. There is no single agent with resources or authority to accomplish this effectively. The USDA's Special Coordinator has limited authority in this area and will submit periodic supplemental reports detailing new research efforts and proposals. Their primary use is expected to be in matching researchers with possible funding organizations.

6.3. USDA RESEARCH

Under the direction of the Secretary much new research has been undertaken at USDA. The Department's research arm, the SEA, accelerated its efforts by developing and implementing a systematic study of explosion control, handling, and utilization of grain dust. A recent SEA Program Review Report (appendix O) announced four major research approaches.

1. Literature review and critical analyses
2. Control and minimization of grain dust generation and accumulation
3. Characterization and classification of grain dusts
4. Mechanism of explosions and baseline explosibility data

In addition to these SEA studies, USDA signed three cooperative agreements with researchers at Kansas State University, Manhattan, Kansas. Studies will:

1. Determine the explosibility of dust resulting from handling corn, wheat, and sorghum, and describe the conditions under which grain dust explosions occur.
2. Identify the detailed chemical and physical processes involved in ignition and subsequent formation of detonation waves in dust clouds.
3. Measure surface areas of corn, milo, wheat, and sorghum dust as well as air spaces between and within dust particles. In addition, the studies will determine how carbon monoxide, methane, carbon disulfide and carbon tetrachloride molecules adhere to dust particles over a range of temperatures.

To further supplement USDA's research effort, on August 29, 1978, FGIS signed a cooperative agreement with a major grain company for a research project on dust concentration monitoring. The study will determine dust concentrations and

dust characteristics inside enclosed work areas and equipment at this company's grain terminals. It will emphasize dust composition, moisture content, and particle size distribution for various grains.

FGIS also initiated a study on grain dust particle sizes. The activities and objectives are as follows:

1. A review of ongoing and completed research related to grain dust and grain dust control systems.
2. A review of present dust control systems to determine their design and efficiency.
3. An attempt to determine the level of dust control needed to reduce dust to an acceptable level in elevators.
4. An analysis of dust samples from various grains collected from diverse dust control systems at export and terminal elevators.
5. To determine the difference in net weights of shipments when various sizes of particles are removed.
6. To compare particle size distribution samples.
7. To establish standards of dust particle sizes to be removed and not returned to the grain.

This study will include comments from the grain industry and is expected to be completed in February 1980.

In February 1979, FGIS contracted to study development methods and uses for a NIC. Such centers, responsible for the collection and organization of specific information, are common throughout government and industry.

This study will determine the following:

1. The data and information which should be collected.
2. The appropriate agency or institution which should be responsible for the NIC.
3. The methods and procedures for collecting data and information.
4. The extent and vehicle of the technology transfer.
5. The proposed funding and staffing to establish and maintain the NIC.

FGIS is considering several prototype electronic dust concentration monitors. If available, these monitors will be tested under actual elevator operating conditions. If these monitors prove successful, FGIS employees could identify hazardous dust concentrations instantly and take immediate remedial action.

Following the International Symposium on Grain Elevator Explosions, OSHA contracted

with NAS to study causes and prevention of grain elevator explosions. This is a two-phase study. The first part will use the information from the Symposium in addition to other sources to derive conclusions about the causes of explosions, the adequacy of safety regulations, and the means to avoid future incidents. The second phase will identify deficiencies and recommend areas needing further research. These studies are to be undertaken by a NAS-sponsored panel.

Nine persons now serve as members of the panel representing the academic and research community, grain and insurance industries, and labor-management. Seven Federal agencies, including USDA, provide liaison representatives to assist the panel in its studies. The USDA is represented by three officials.

6.4. CONCLUSIONS

Based on the opinions and concepts developed and presented during the course of the Symposium, and other information in this chapter, the Task Force concludes the following:

- The presence of large amounts of dust in the U.S. grain handling system is a fire and explosion hazard.

- A variety of possible solutions to this fire and explosion problem are currently available.

- The lack of adequate technology transfer in terms of research information, safe operating techniques, and other safety information has affected the severity of the grain dust fire and explosion problem in grain elevators.

- Research and other activities relating to grain dust explosions are for the most part not directed nor coordinated. This wastes resources and duplicates efforts. Lack of a mechanism for technology transfer prevents timely application of possible solutions.

6.5. RECOMMENDATIONS

Although the Task Force concurs with many of the opinions expressed during the Symposium, solving the problems of grain dust fires and explosions must involve a choice. This is the selection of technology or procedures which can be applied effectively, economically, and quickly. Central to this concept is the principle that any choice must

be made not only within the context of desired results but also within parameters defined by present conditions and constraints.

The Symposium consolidated pertinent information and possible techniques applicable to the problems of grain dust fires and explosions in handling facilities. The opinions and the findings presented in this report have been considered in light of present conditions and practices in the U.S. grain handling system. In conjunction with additional assessments of how techniques are likely to be applied, probable levels of application, and the desired results of this application, the Task Force recommends the following:

- Remove dust from the grain stream in handling facilities.

- Prohibit reintroduction of collected dust in grain handling facilities.

- Apply other important techniques including:

- Implement improved housekeeping programs;

- Implement better maintenance programs;

- Reduce available ignition sources;

- Reduce human error by providing improved operator training as well as more safety and hazard recognition training;

- Design and operate new facilities to reduce dust explosion problems.

- Designate responsibility to a single Government agency for monitoring and enforcing implementation of explosion prevention measures, but only if the results of voluntary compliance have proved inadequate.

- Establish a NIC geared to the problems of grain dust fires and explosions.

- Develop and use institutionalized mechanisms to alert all of those involved in grain handling to new techniques and information which can be used to improve safety in grain handling facilities.

- Establish a permanent interagency council to evaluate present and future needs of the grain handling and processing industries as they concern grain dust fires and explosions and other operational problems. The interagency council should provide necessary guidance and direction to the Government and to the grain handling and processing industries.

Chapter 7

STUDIES

The Task Force developed additional background material while addressing the problems involved in grain dust fires and explosions. This material is presented in four separate studies contained in this chapter. These are as follows:

- (1) Static-Ambient Dust;
- (2) The U.S. Export Handling System;
- (3) Comparison of U.S. and Foreign Grain Handling; and
- (4) Relative Humidity—A Pilot Study.

Appropriate conclusions and recommendations follow each individual study.

7.1. AMBIENT CONCENTRATIONS RESULTING FROM STATIC DUST

Grain dust is the fuel for fires and explosions in grain handling facilities. The unfortunate reality is that U.S. grain handling facilities are dusty. The Task Force derived ambient dust concentrations which would result if certain levels of accumulated dust were dispersed evenly into the air inside a grain elevator.

7.1.1. Procedure

Minimum and maximum density figures for four grain dusts (wheat, corn, milo, and soybean) were selected (ref. 29). Volumes and weights of dust which would cover 100 ft² from 1/16" to 1" deep were computed. Ambient dust concentrations in g/m³ were then determined on the assumption that all of the static dust could be dispersed into the volume of air (measuring 10 ft x 10 ft x 10 ft = 1,000 ft³) which lies above this hypothetical 100 ft² layer of dust.

Table 24 presents ambient dust concentrations which would result if layers of corn dust from 1/16" to 1" in depth on a surface of 100² (10 feet x 10 feet) were completely and evenly dispersed in a volume of air measuring 1,000 ft³ (a cube, 10 feet x 10 feet x 10 feet). Tables 25 through 27 present similar information for wheat, milo, and

soybean dusts. This material is presented graphically in figure 11.

The dust density figures repeated in each column 2 are minimums and maximums for each grain dust. The minimum figures approximate a sample of grain dust which has a high concentration of fines and has not undergone any extensive packing. The maximum figures approximate a sample of grain dust which has a high concentration of large particles and has undergone some packing.

The density of dust accumulations deposited on ceilings or on the upper parts of walls should be similar to the minimum figures. The density of dust deposited on floors and the lower parts of walls should be similar to the maximum figures in which packing is thought to be a factor.

Although a minimum explosible concentration as low as 20 g/m³ has been cited by one authority (ref. 30), even the largest estimate encountered in the literature (ref. 4), 55 g/m³ (for mixed grain), is exceeded by all except one of the possible dust concentrations. The exception is the minimum density given for milo dust at 1/16".

Assume there exists in a grain elevator one room, 10 ft x 10 ft x 10 ft, or 1,000 ft³. This room has, in addition to a floor surface on which dust can accumulate, a ceiling and four walls. If dust accumulates evenly on all of these surfaces and is dispersed into the volume of air contained by that room, ambient dust concentrations could be up to six times greater than those amounts listed in the tables.

7.1.2. Limitations

In practice, the following conditions can be assumed.

1. Dust will not have been evenly deposited on all surfaces.
2. Barring a severe disturbance, not all of the dust would be dispersed into the room at one time.

Table 24.—Possible ambient (corn) dust concentrations from static dust layers

Depth of dust 1	Density of dust (lbs/ft ³) min./max. 2	Volume of dust (ft ³)/ (10' x 10' x 100 ft ²) 3	Weight of dust (lbs) 4	Concentration (lbs/ft ³) per 1000 ft ³ (10' x 10' x 10') 5	Concentration (g/m ³) 6
1/16"	8.2368 21.1536	.5208	4.2897 11.0168	.0042897 .0110168	69.492 178.469
1/8"		1.0416	8.5794 22.0336	.0085794 .0220336	138.985 356.938
3/16"		1.5624	12.8691 33.0504	.0128691 .0330504	208.477 535.407
1/4"		2.0832	17.1588 44.0672	.0171588 .0440677	277.970 713.877
5/16"		2.6040	21.4485 55.0840	.0214485 .0550840	347.462 892.346
3/8"		3.1248	25.7382 66.1008	.0257382 .0661008	416.954 1070.815
7/16"		3.6456	30.0279 77.1176	.0300279 .0771176	486.447 1249.284
1/2"		4.1664	34.3176 88.1344	.0343176 .0881344	555.939 1427.753
9/16"		4.6872	38.6073 99.1512	.0386073 .0991512	625.432 1606.222
5/8"		5.2080	42.8970 110.1680	.0428970 .1101680	694.924 1784.692
11/16"		5.7288	47.1876 121.1848	.0471876 .1211848	764.416 1963.161
3/4"		6.2496	51.4764 132.2016	.0514764 .1322016	833.909 2141.630
13/16"		6.7704	55.7661 143.2184	.0557661 .1432184	903.401 2320.099
7/8"		7.2912	60.0558 154.2352	.0600558 .1542352	972.893 2498.568
15/16"		7.8120	64.3455 165.2520	.0643455 .1652520	1042.386 2677.037
1"		8.3328	68.6352 176.2688	.0686352 .1762688	1111.878 2855.507

3. Dust would not be evenly dispersed throughout the entire enclosed volume.

4. For larger enclosed volumes, such as those commonly found in grain elevators, the ratio of surface area (of floor, ceiling, and walls) to volume of enclosed space becomes smaller as the volume and surface increase.

Volumes of space found in grain elevators provide the following examples which help to explain the mechanism involved. With a volume of 1,000 ft³ or 10 ft x 10 ft x 10 ft, the surface area of the floor, ceiling, and walls would be 600 ft² giving a ratio of 6 : 10. With a volume of 20,000 ft³ or 20 ft x 100 ft x 10 ft, the surface area of the floor, the ceiling, and four walls required to enclose that space would be 6,400 ft². The ratio of surface area to volume in this case would be 3.2 : 10.

A rectangular, solid-type configuration is common to grain elevator headhouses. As the volume

of enclosed space increases, the relative amount of surface area needed to enclose that space with floor, ceiling, and walls becomes proportionately smaller. If dust deposits are held at a constant depth, the amount of dust available for dispersal into the enclosed volume varies directly with the total surface area. Any resulting ambient dust concentration in the enclosed volume would also be proportionately smaller, even though the actual amount of dust available is increasing.

7.1.3. Discussion

Although as yet not supported empirically, it can be assumed that relatively small localized areas could exist inside a handling facility in which a minimum explosible concentration could be created by the dispersion of a minute quantity of dust. For example, if a 2 ft³ space is assumed to exist contiguous to a floor surface, its dimensions could be 15 1/8 in x 15 1/8 in x 15 1/8 in. The

Table 25.—Possible ambient (wheat) dust concentrations from static dust layers

Depth of dust 1	Density of dust (lbs/ft ³) min./max. 2	Volume of dust (ft ³)/ (10' x 10' x 100 ft ²) 3	Weight of dust (lbs) 4	Concentration (lbs/ft ³) per 1000 ft ³ (10' x 10' x 10') 5	Concentration (g/m ³) 6
1/16"	10.6704 16.1616	.5208	5.5571 8.4170	.0055571 .0084170	90.024 136.352
1/8"		1.0416	11.1142 16.8340	.0111142 .0168340	180.048 272.705
3/16"		1.5624	16.6713 25.2510	.0166713 .252510	270.073 409.057
1/4"		2.0832	22.2284 33.6680	.0222284 .0336680	360.097 545.410
5/16"		2.6040	27.7855 42.0850	.0277855 .0420850	450.121 681.762
3/8"		3.1248	33.3426 50.5020	.0333426 .0505020	540.145 818.115
7/16"		3.6456	38.8997 58.9190	.0388997 .0589190	630.170 954.467
1/2"		4.1664	44.4578 67.3360	.0444578 .0673360	720.194 1090.820
9/16"		4.6872	50.0139 75.7530	.0500139 .0757530	810.218 1227.172
5/8"		5.2080	55.5710 84.1700	.0555710 .0841700	900.242 1363.525
11/16"		5.7288	61.1281 92.5870	.0611281 .0925870	990.266 1499.877
3/4"		6.2496	66.6852 101.0040	.0666852 .1010040	1080.291 1636.230
13/16"		6.7704	72.2423 109.4210	.0722423 .1094210	1170.315 1772.582
7/8"		7.2912	77.7994 117.8380	.0777994 .1178380	1260.339 1908.935
15/16"		7.8120	83.3565 126.2550	.0833565 .1262550	1350.363 2045.287
1"		8.3328	88.9136 134.6720	.0889136 .1346720	1440.388 2181.640

amount of corn dust (density = 8.2368 pounds/ft³) required to create an explosible concentration of 55 g/m³ in this volume would be 3.11487 grams. If this amount of dust were evenly deposited on the floor surface of the volume, a layer of dust less than a half of 1/64 of an inch would result. Assuming that this area of floor is covered by 1/16 in. of dust, a person walking through this area would probably kick up enough dust to create an explosible concentration of 55 g/m³ in the small 2 ft³ volume. This seemingly innocent scenario could become lethal with the addition of the appropriate ignition source.

The implications of this analysis become even more crucial when regarded in light of the often repeated theory of dust explosion propagation in grain handling facilities—the “chain of explosions” theory. This states that a series of successively more violent explosions result from a relatively minor initial explosion. Pressure waves

preceding the flame front(s) disperse static dust accumulations into the atmosphere. As the explosion chain progresses, more and more fuel becomes available to the flame front(s). This activity can be likened to the expanding ripples which occur on the surface of a still pond after a pebble is tossed into it.

7.1.4. Conclusions

Considering the hypothetical nature of this analysis of static dust concentrations, together with the practical limitations and physical parameters within grain handling facilities, the Task Force concludes:

- Even the smallest accumulations of static dust present a serious hazard and given the proper conditions may initiate a primary explosion in a grain handling facility.

Table 26.—Possible ambient (soybean) dust concentrations from static dust layers

Depth of dust 1	Density of dust (lbs/ft ³) min./max. 2	Volume of dust (ft ³)/ (10' x 10' - 100 ft ²) 3	Weight of dust (lbs) 4	Concentration (lbs/ft ³) per 1000 ft ³ (10' x 10' x 10') 5	Concentration (g/m ³) 6
1/16"	13.9152	.5208	7.2470	.0072470	117.400
	16.5984		8.6444	.0086444	140.038
1/8"		1.0416	14.4940	.0144940	234.800
			17.2888	.0172888	280.075
3/16"		1.5624	21.7410	.0217410	352.200
			25.9332	.0259332	420.113
1/4"		2.0832	28.9880	.0289880	469.600
			34.5776	.0345776	560.151
5/16"		2.6040	36.2350	.0362350	587.000
			43.2220	.0432220	700.188
3/8"		3.1248	43.4820	.0434820	704.400
			51.8664	.0518664	840.226
7/16"		3.6456	50.7290	.0507290	821.800
			60.5108	.0605108	980.264
1/2"		4.1664	57.9760	.0579760	939.200
			69.1552	.0691552	1120.302
9/16"		4.6872	65.2230	.0652230	1056.600
			77.7996	.0777996	1260.339
5/8"		5.2080	72.4700	.0724700	1174.000
			86.4440	.0864440	1400.377
11/16"		5.7288	79.7170	.0797170	1291.400
			95.0884	.0950884	1540.415
3/4"		6.2496	86.9640	.0869640	1408.800
			103.7328	.1037328	1680.452
13/16"		6.7704	94.2110	.0942110	1526.200
			112.3772	.1123772	1820.490
7/8"		7.2912	101.4580	.1014580	1643.600
			121.0216	.1210216	1960.528
15/16"		7.8120	108.7050	.1087050	1761.000
			129.6660	.1296660	2100.565
1"		8.3328	115.9520	.1159520	1878.400
			138.3104	.1383104	2240.603

7.1.5. Recommendations

- Require the development and implementation of comprehensive operations plans which include programs for maintenance, housekeeping, safety, and security.

7.2. THE EXPORT GRAIN HANDLING SYSTEM

The present U.S. grain handling system, taken as a whole, generates grain dust as a normal by-product of operation. Many different factors are involved, but most authorities agree that increased volumes of grain handled and increased handling speeds contribute to an apparent increase in grain dustiness.

The actual amounts of dust generated during handling are variable. In addition to these factors, the kind of grain handled and the relative proportions of each grain as a component of total throughput should not be underestimated.

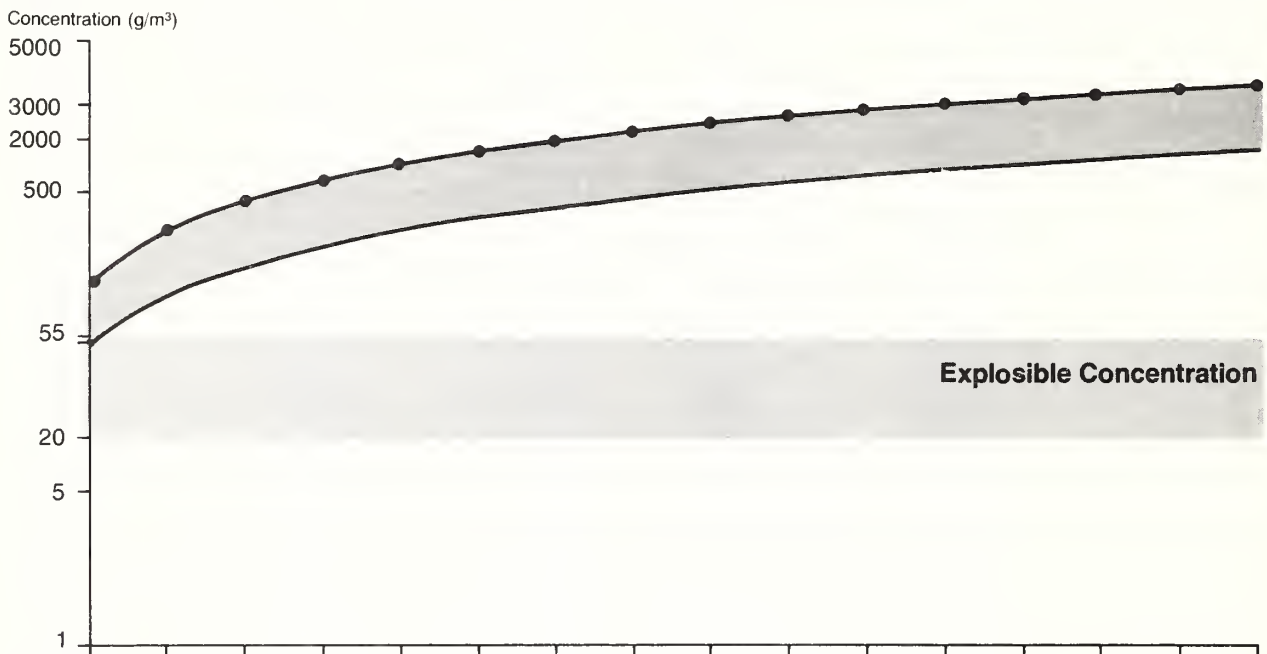
It is well documented that the rapid burning of grain dust inside inadequately vented grain elevators has been responsible for the destruction of more than 250 handling facilities since 1958. This grain dust is a byproduct of the grain handling system. The amount of dust generated is roughly proportional to the volumes and types of grain handled. The more dust present, the greater the chance for ignition. Changes in the amounts and types of grain handled should correspond to changes in the likelihood of dust explosion and fire hazards and, therefore, to changes in the number of explosion incidents in the long run. This may be especially significant when throughput approaches handling capacity design limits.

The U.S. grain handling system is not static. It responds to various agricultural marketing pressures, as well as to many other economic, transportation, and social factors. This responsiveness, at least to one factor, is shown clearly by comparing the grain production figures in table 28. Total

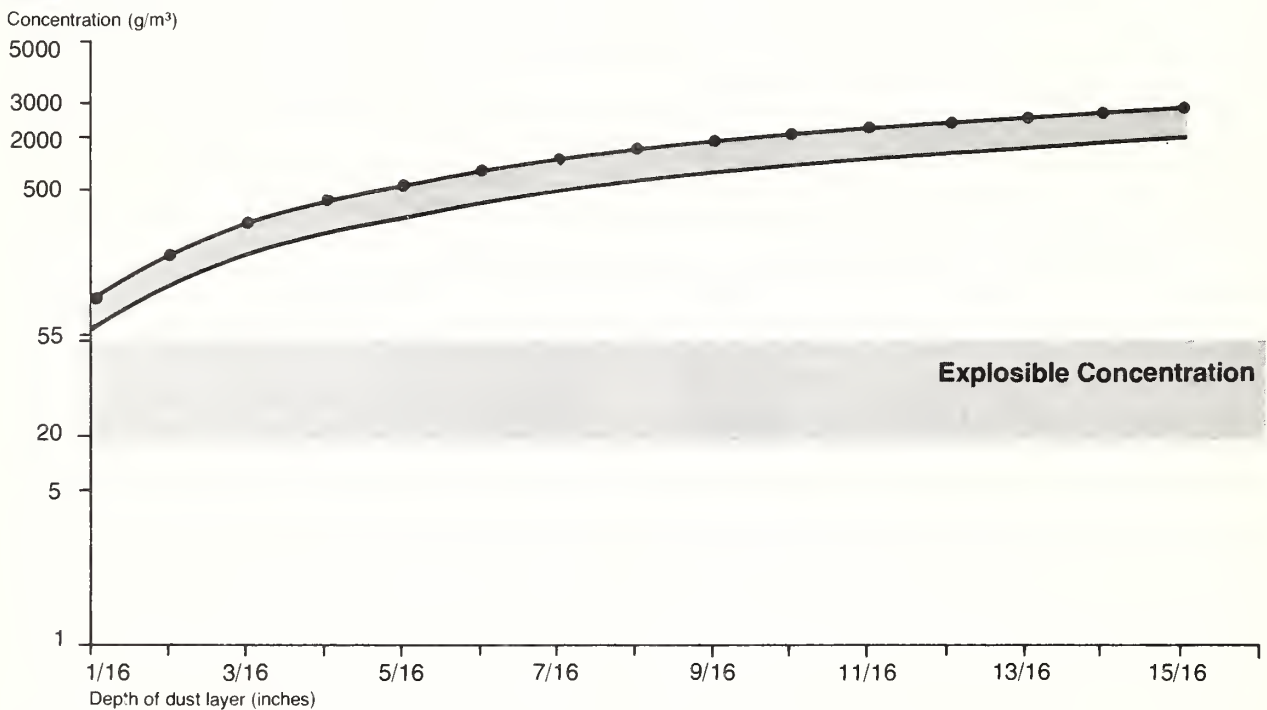
Figure 11

Dispersal of Layered Dust and Airborne Concentration

A Corn



B Wheat



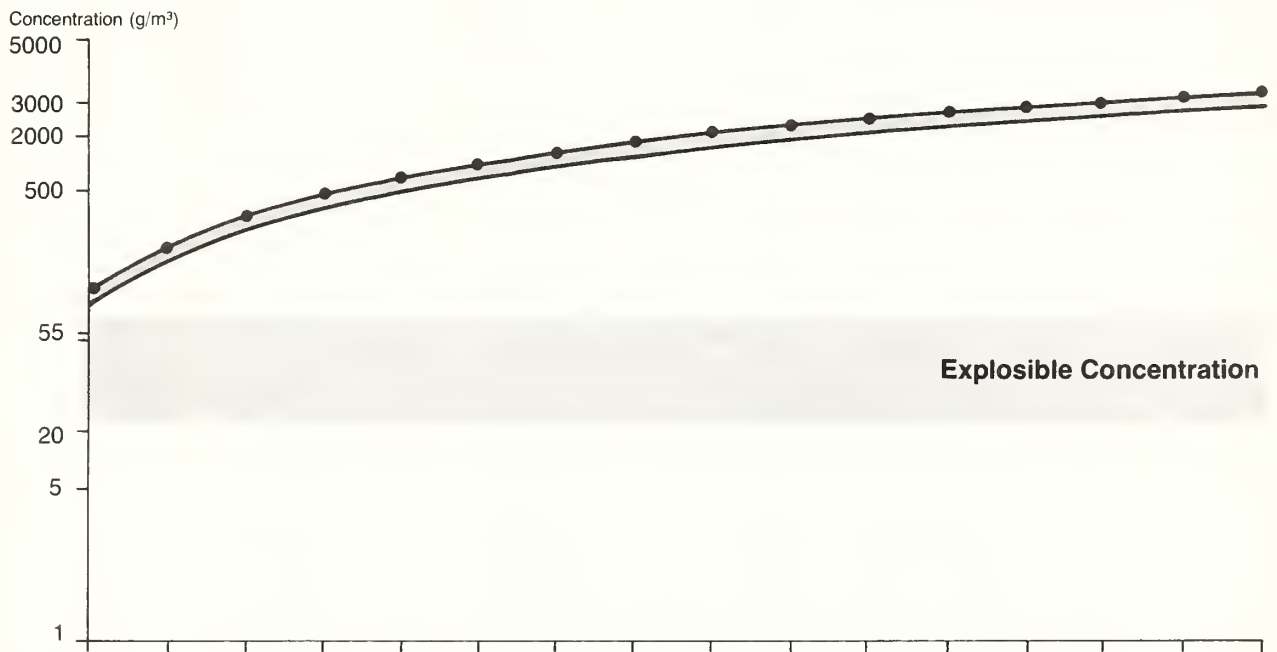
Dust layer covers 100 ft² of floor area. Airborne Concentration results from dispersal of dust in layer.

Figure 11 Dispersal of Layered Dust and Airborne Concentration

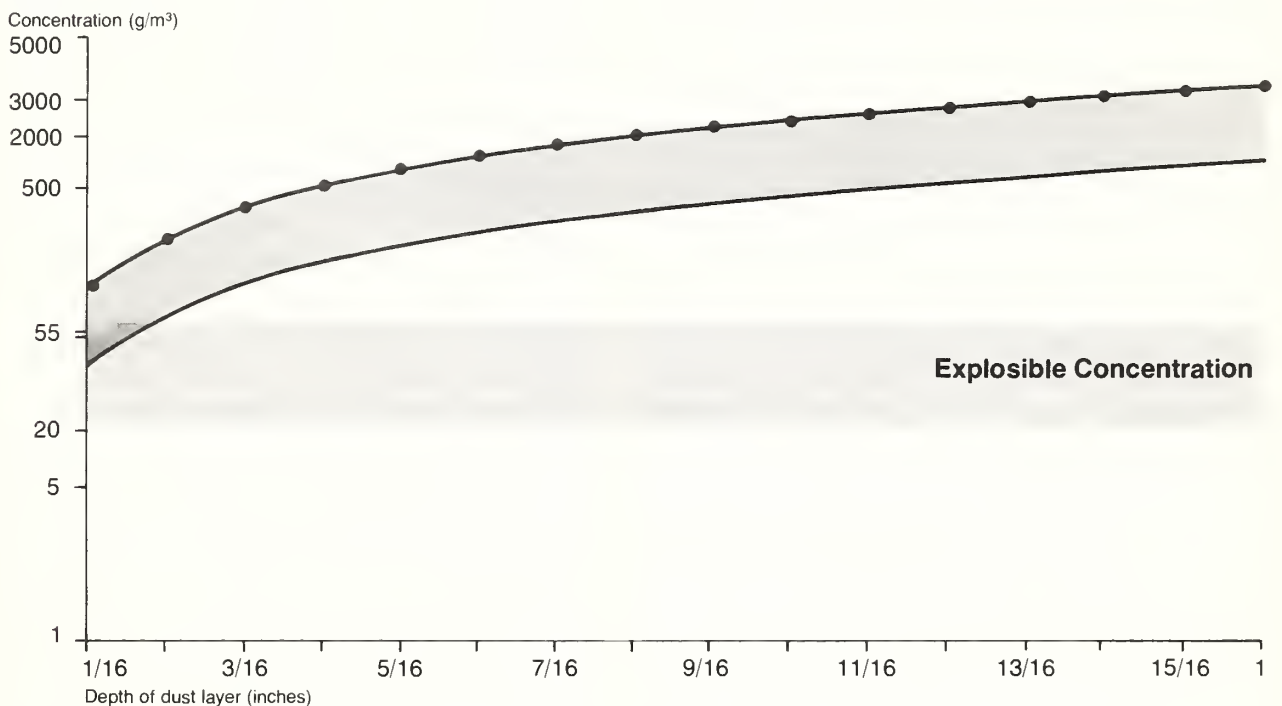
Figure 11 (continued)

Dispersal of Layered Dust and Airborne Concentration

C Soybeans



D Milo



Dust layer covers 100 ft² of floor area. Airborne Concentration results from dispersal of dust in layer.

Table 27.—Possible ambient (milo) dust concentrations from static dust layers

Depth of dust 1	Density of dust (lbs/ft ³) min./max. 2	Volume of dust (ft ³)/ (10' x 10' 100 ft ²) 3	Weight of dust (lbs) 4	Concentration (lbs/ft ³) per 1000 ft ³ (10' x 10' x 10') 5	Concentration (g/m ³) 6
1/16"	5.8656	.5208	3.0548	.0030548	49.487
	16.9728		8.8394	.0088394	143.196
1/8"		1.0416	6.1096	.0061096	98.974
			17.6788	.0176788	286.393
3/16"		1.5624	9.1644	.0091644	148.461
			26.5182	.0265182	429.589
1/4"		2.0832	12.2192	.0122192	197.948
			35.3576	.0353576	572.786
5/16"		2.6040	15.2740	.0152740	247.435
			44.1970	.0441970	715.982
3/8"		3.1248	18.3288	.0183288	296.922
			53.0364	.0530364	859.179
7/16"		3.6456	21.3836	.0213836	346.409
			61.8758	.0618758	1002.375
1/2"		4.1664	24.4384	.0244384	395.895
			70.7152	.0707152	1145.571
9/16"		4.6872	27.4932	.0274932	445.382
			79.5546	.0795546	1288.768
5/8"		5.2080	30.5480	.0305480	494.869
			88.3940	.0883940	1431.964
11/16"		5.7288	33.6028	.0336028	544.356
			97.2334	.0972334	1575.161
3/4"		6.2496	36.6576	.0366576	593.843
			106.0728	.1060728	1718.357
13/16"		6.7704	39.7124	.0397124	643.330
			114.9122	.1149122	1861.554
7/8"		7.2912	42.7672	.0427672	692.817
			123.7516	.1237516	2004.750
15/16"		7.8120	45.8220	.0458220	742.304
			132.5910	.1325910	2147.947
1"		8.3328	48.8768	.0488768	791.791
			141.4304	.1414304	2291.143

grain production had increased by 80 percent, from 7.5 billion bushels in 1962 to nearly 11.6 billion bushels in 1975. The handling system had to respond to accommodate this increase in production.

The export handling system has experienced disproportionate pressures when compared to the system as a whole. While increases in grain production and use can to some extent be distributed throughout the entire system of approximately 15,000 handling, storage, and processing facilities, any increase in grain exports must be handled by about 85 export terminals.

Data collected during the survey of U.S. grain export facilities (see section 4.1.) indicates that only about 27 percent of the export facilities had been built after 1962. Table 28 shows that at the end of the 1962 marketing year total grain exports from the United States were nearly 1.6 billion bushels. At the end of the 1975 marketing year total grain exports had increased to more than 3.8

billion bushels. This is a 145 percent increase over the 1962 figure. If it is assumed that the elevators built before 1962 were operating at or near their maximum handling capacity, then nearly all of the increase in grain exports, approximately 2.3 billion bushels, will have been handled by the elevators built after 1962. In effect, less than a third of the export elevators may handle almost half of our grain exports. It is clear that one trend in export elevator construction since 1962 has been the building of facilities with increased handling capacities.

The following discussion presents data showing how grain exports have been apportioned throughout the export grain handling system. It also shows some clearly defined trends which have developed. It is limited to calendar years 1975 through 1977. The discussion is based on export inspections performed by FGIS. This information is then related to the incidence of dust explosions at export facilities.

Table 28.—U.S. grain production and exports by marketing year¹

Production (million bushels)

Year	Total Production	Rice	Corn	Sorghum	Oats	Barley	Wheat	Rye	Soybeans	Flaxseed
1962	7537.4	146.8	3606.3	510.3	1012.2	427.7	1092.0	40.7	669.2	32.2
1963	8025.3	156.2	4019.2	585.4	965.5	392.8	1146.8	29.2	699.2	31.0
1964	7416.3	162.6	3484.3	489.8	852.3	386.1	1283.4	32.5	700.9	24.4
1965	8497.7	169.5	4102.9	672.7	929.6	393.1	1315.6	33.3	845.6	35.4
1966	8551.5	188.9	4167.6	715.0	803.3	392.1	1304.9	27.8	928.5	23.4
1967	9509.7	198.6	4860.4	755.3	793.8	373.7	1507.6	23.9	976.4	20.0
1968	9502.7	231.4	4449.5	731.3	950.7	426.2	1556.6	23.0	1107.0	27.0
1969	9655.2	204.2	4687.1	730.0	965.9	427.1	1442.7	30.2	1133.1	34.9
1970	8899.5	186.2	4151.9	683.2	917.2	416.1	1351.6	36.8	1127.1	29.4
1971	10904.7	190.6	5641.1	868.0	881.3	462.4	1617.8	49.2	1176.1	18.2
1972	10536.0	189.9	5573.3	801.4	692.0	421.7	1544.9	28.3	1270.6	13.9
1973	11154.2	206.1	5646.8	923.2	666.9	417.4	1705.2	24.7	1547.5	16.4
1974	9492.7	249.8	4663.6	622.7	613.8	298.7	1796.2	17.5	1216.3	14.1
1975	11584.3	284.4	5829.0	753.0	642.0	374.4	2122.5	16.0	1547.4	15.6
1976	11614.8	257.0	6266.4	719.8	546.3	372.5	2142.4	15.0	1287.6	7.8

Exports (million bushels)

Year	Total Exports	Rice ²	Corn	Sorghum	Oats	Barley	Wheat ³	Rye	Soybeans	Flaxseed
1962	1564.6	78.9	416	113	30	73	649	20.2	180.5	4.4
1963	1822.8	92.9	500	107	6	68	846	12.0	187.2	3.7
1964	1820.2	94.4	570	148	5	59	723	2.2	212.2	6.4
1965	2272.9	96.2	687	266	34	78	852	3.8	250.6	5.3
1966	1963.3	114.7	487	248	22	48	771	4.2	261.6	6.8
1967	2012.4	126.4	633	166	11	36	765	3.0	266.6	5.4
1968	1628.1	124.7	536	106	8	12	544	1.1	286.8	9.5
1969	1922.3	126.4	612	126	5	10	603	.8	432.6	6.5
1970	2048.5	103.3	517	144	19	84	741	3.2	433.8	3.2
1971	2137.3	126.4	796	123	21	41	610	2.2	416.8	.9
1972	3309.8	120.0	1258	212	19	70	1135	6.5	479.4	9.9
1973	3521.6	110.4	1243	234	57	93	1217	27.5	539.1	.6
1974	3023.0	154.4	1149	212	19	42	1019	6.5	420.7	.4
1975	3833.8	125.6	1711	229	14	24	1173	1.1	555.1	1.0
1976	3666.5	145.8	1684	246	10	66	950	.4	564.1	.2

Note: Production and export figures have been rounded to the nearest 100,000 bushels where possible.

¹ Year beginning June 1 for barley, flaxseed, oats, rye, and wheat. August 1 for rice; September 1 for soybeans; and October 1 for corn and sorghum.

² Includes rough rice and milled rice converted to rough rice equivalents.

³ Includes wheat, flour, and other products expressed in wheat equivalents.

Compiled from *Agricultural Statistics 1978*, USDA, Government Printing Office, Washington, D.C. 1978.

In addition, this section presents material which approximates the degree of use or "system loading" for the various export marketing regions. This allows comparison, not only among different years in the same region, but also among different regions. If refined, this type of analysis would be invaluable in pinpointing those handling trends (as detailed in section 7.2.1.) which are thought to increase the possibility of grain dust fires and explosions.

7.2.1. Statistical Overview of Grain Exports

Figure 12 shows the five FGIS Regions used in this study. Regarding grain exports, Regions I, II, III, and V are significant. During the years cov-

ered by the study, Region IV, the Kansas City Region, contained no grain handling facilities whose primary function was the exporting of grain.

Tables 29 through 32 present inspected U.S. grain exports by FGIS Regions. These tables cover the calendar years 1975 through 1977 and the first 6 months of 1978. Major export areas and numbers of export terminals are listed under each Region.

Exports of three grains; wheat, corn, and soybeans, generally account for about 92 percent of total inspected grain exports. This percentage does not include rice exports.

Figure 12

Federal Grain Inspection Service Regional Boundaries



Figure 12 Federal Grain Inspection Service Regional Boundaries

There is a discrepancy in the total export volume presented for 1976 in table 28 and the inspected exports for 1976 in table 30. In part, this results from the exclusion of rice exports in the latter table, the use of marketing years in table 28 as opposed to the use of calendar years in table 30, and the inclusion of exported grain products as grain equivalents in table 28.

The figures for Region II in tables 29 through 32 include exports of U.S. grain transshipped through Canadian elevators. Such grain may have received two separate export inspections, one at a U.S. port and another at the Canadian port. The numbers of Canadian export elevators handling this grain are also included in the totals under "Number of Export Facilities." Final totals may be inflated as a result. However, this is offset in part by the exclusion of some export rail shipments.

Export inspection figures for wheat, corn, and soybeans are summarized by FGIS Region and year and presented graphically in figure 13.

Total inspected exports have increased since 1975. While there were 3.17 billion bushels of inspected grain exports in 1975, the 1976 total reached 3.58 billion bushels. In 1977 there was a slight decline to 3.39 billion bushels although this

was still above the 1975 base year. The 1978 totals (not shown) exceeded the 1976 high with inspected grain exports of 4.20 billion bushels.

As shown in table 33, total inspected grain exports in 1976 increased nearly 13 percent over the 1975 total. The 1977 total represented only a 6 percent increase over the 1975 total.

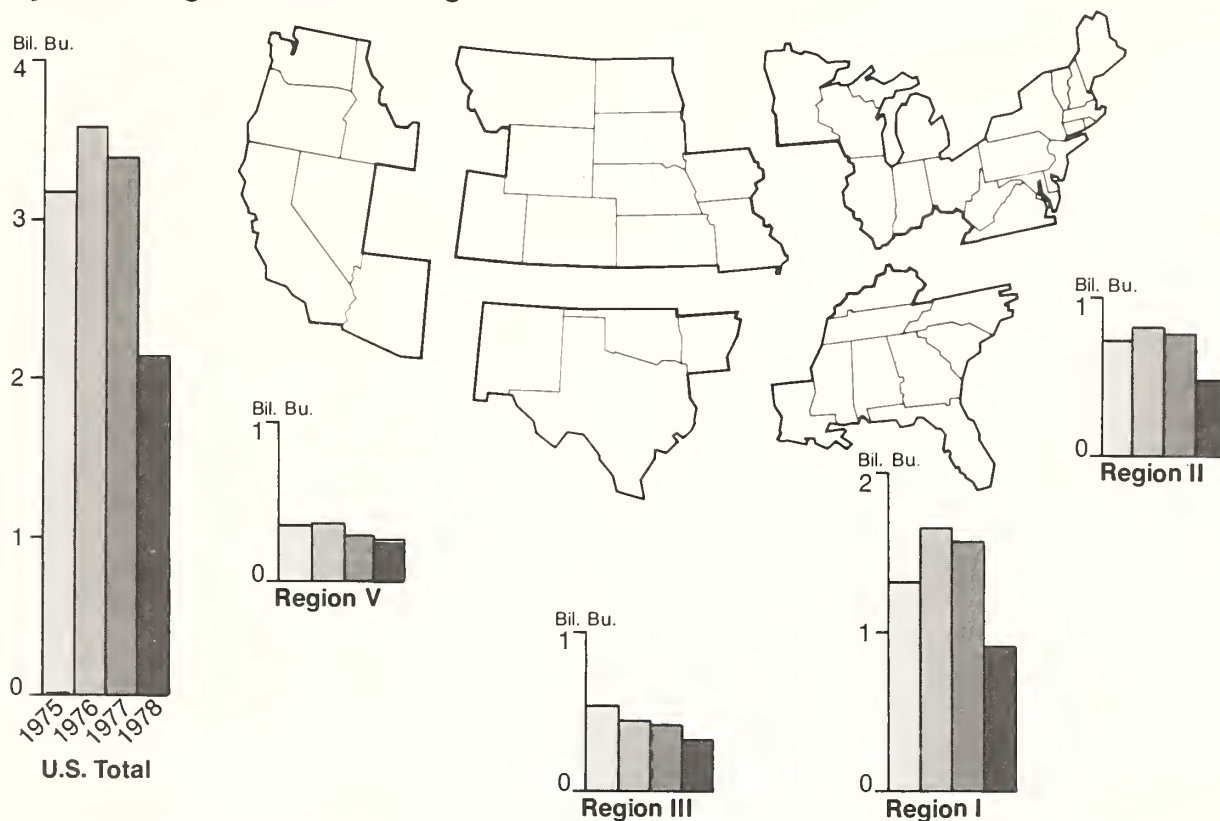
The majority of U.S. grain exports are handled by Gulf Coast terminals. In 1975, Gulf Coast ports in FGIS Regions I and III handled 57 percent of inspected wheat, corn, and soybean exports.

This figure increased to 59 percent in 1976 and remained relatively unchanged in 1977. This material is contained in table 34.

Exports of wheat, corn, and soybeans in 1976 increased 13 percent over 1975 and by 6 percent in 1977. Exports of these grains through the Gulf in 1976 had increased 15 percent over the previous year's exports through the same area. The increase in 1977 was 10 percent over the 1975 figure. Comparing this data with that presented in table 33, it can be seen that the rate at which Gulf Coast exports are increasing is greater than the rate of increase for the export grain handling system taken as a whole.

Figure 13

Inspected United States Wheat, Corn, Soybean, and Other Grain Exports by FGIS Regions, 1975 through First Half of 1978



Source: Raw Data provided by FGIS.

Yearly totals include export shipments of U. S. grain from Canada. Some lots of grain may be inspected for export twice; once when exported from the U. S., and again when shipped from Canada. Data may exceed actual exports.

No reporting from Region IV. 1978 equals first six months only.

Figure 13 Inspected U.S. Wheat, Corn, Soybeans, and Other Grain Exports by FGIS Regions, 1975-Through First Half 1978

7.2.2. Corn Exports

Not only is the volume of grain exports increasing but the export volumes of the component grains have changed in relation to each other. As shown in table 28, in 1962 wheat was the major export grain with 649 million bushels exported during the marketing year. Corn was a distant second with 416 million bushels and soybeans ranked third with 180.5 million bushels. In 1975, corn was the number one export grain in volume with 1.71 billion bushels. Wheat was number two with 1.17 billion bushels exported and soybeans were still in third place with a volume of 555 million bushels.

At the end of the 1975 corn marketing year, corn exports had increased 311 percent over 1962 corn exports. During the same period, U.S. corn

production had increased only 62 percent. Total grain production had increased 54 percent.

As previously stated, the export grain handling system has been subjected to pressures much greater than those brought to bear on the handling system as a whole. A major factor could be the enormous increase in the volume of corn exports. Table 35 shows how inspected corn exports have been apportioned throughout the various FGIS Regions during calendar years 1975 to 1977. It also shows the percent increase in corn exports from the 1975 base year. Inspected corn exports through Gulf Coast terminals comprised about 68 percent of all inspected U.S. corn exports.

Corn, as it is presently harvested and dried, generates relatively large amounts of dust during

Table 29.—Total inspected U.S. grain exports by regions (1,000 bushels) 1975*

	Number of export facilities	Wheat	Corn	Soybeans	Other	Total
REGION I						
South Atlantic	1	964	8123	4071		13158
Mississippi River	9	129494	759437	283134		1172065
Eastern Gulf	3	48897	22300	47343		118540
Total	13	179355	789860	334548		1303763
REGION II						
Canadian Lakes	5	5688	0	0		5688
U.S. Lakes	21	131970	112833	57688		302471
North Atlantic	3	24297	66621	10164		101082
South Atlantic	5	54369	223818	35755		313942
Total	34	216324	403272	103587		723183
REGION III						
North Texas	9	375731	90697	18199		484627
South Texas	3	45230	609	0		45839
Total	12	420961	91306	18199		530466
REGION V						
Columbia River	7	218874	0	8		218882
Puget Sound	3	66850	0	0		66850
California	4	56333	5277	0		61610
Total	14	342057	5277	8		347342
			Oats	11803		
			Barley	24961		
			Flaxseed	960		
			Sorghum	229635		
			Rye	954		
Totals	73	1158697	1289715	456342	268313	3173067

*Excludes export rail shipments of wheat, corn, and soybeans from Region III, South Texas.

Source: Data provided by FGIS.

handling. Martin and Sauer have found that, during bin transfers of corn, the amount of dust generated and collected during the handling exceeded 0.1 percent of the total weight of the corn handled. Dust generated and collected during similar bin transfers of wheat was "almost inconsequential in comparison with corn dustiness" (ref. 23).

From table 28 it can be seen that, if corn exports increased 311 percent during the 1962 through 1975 period, the net mean yearly increase would be about 24 percent. This represents the normal, long range, yearly growth in corn exports for the entire export system. Comparison of this figure with those in table 35, indicates that the system as a whole experienced a greater than normal increase in corn exports in 1976. The 1977 totals, although a net decrease from 1976, still represent a substantial increase in corn exports

over 1975. The percent increase in this year more closely approximates the derived norm of 24 percent.

Table 36 shows the percentage of total exports made up of corn for each region and for the United States as a whole. Again taking 1975 as a reference point, it can be seen that in most regions corn exports comprise a larger and larger share of the total regional grain exports. The export corn component in nearly every region rose dramatically in 1976. In 1978 corn exports (not shown) from Gulf Coast terminals comprised a slightly smaller portion of total Regional grain exports, about 47 percent. This compares with 53 percent in 1977 and 56 percent in 1976.

A reliable, long term data base is not available. However, cursory examination of existing dust

Table 30.—Total inspected U.S. grain exports by regions (1,000 bushels) 1976*

	Number of export facilities	Wheat	Corn	Soybeans	Other	Total
REGION I						
South Atlantic	1	1025	14336	4362		19723
Mississippi River	9	166549	984788	354654		1505991
Eastern Gulf	3	16005	67255	63258		146518
Total	13	183579	1066379	422274		1672232
REGION II						
Canadian Lakes	5	19905	0	0		19905
U.S. Lakes	20	57311	155149	60079		272539
North Atlantic	3	24018	75757	8455		108230
South Atlantic	5	39544	312061	51463		403068
Total	33	140778	542967	119997		803742
REGION III						
North Texas	9	268776	117595	18569		404940
South Texas	3	40342	572	0		40914
Total	12	309118	118167	18569		445854
REGION V						
Columbia River	7	235315	0	0		235315
Puget Sound	3	77540	492	113		78145
California	4	42938	5459	0		48397
Total	14	355793	5951	113		361857
			Oats	9239		
			Barley	56471		
			Flaxseed	387		
			Sorghum	230408		
			Rye	130		
Totals	72	989268	1733464	560953	296635	3580320

*Excludes export rail shipments of wheat, corn, and soybeans from Region III, South Texas.

Source: Data provided by FGIS.

explosion and grain marketing information indicates that there may be a correlation between the yearly volume changes in corn exports and corn dust handled and changes in the numbers of grain elevator explosion incidents.

This tentative hypothesis becomes especially critical in terms of the export segment of the grain handling system. Data was available only for the years 1975 through 1977. During calendar year 1975, there were no explosions reported at export terminals. In 1976, two occurred in the Great Lakes region (FGIS Region II) and one occurred at a Gulf Coast location (FGIS Region III); a total of three dust explosion incidents for the year. In 1977, one incident was recorded for the Great Lakes region and three at Gulf Coast terminals (FGIS Regions I and III); a total of four dust explosion incidents for the year.

In 1976 inspected grain exports passing through the Gulf Coast terminals increased 15 percent over the 1975 volume (table 34). The 1977 volume was 10 percent above the 1975 total. Table 35 shows that in 1976 inspected corn exports passing through Gulf Coast terminals represented a 35 percent increase in the volume of corn handled by those terminals in 1975. The total 1977 volume represented a 22 percent increase over 1975. In the Great Lakes the volume of corn exported exceeded 1975 figures both in 1976 and 1977—38 and 26 percent, respectively. Table 35 shows that in 1976 total inspected U.S. corn exports increased 34 percent over 1975 and, in 1977, 22 percent over 1975. The similarity between the figures for the entire U.S. grain export system and those of the Gulf Coast result from the fact that more than two-thirds of all inspected corn exports are handled by Gulf Coast terminals.

Table 31.—Total inspected U.S. grain exports by regions (1,000 bushels) 1977*

	Number of export facilities	Wheat	Corn	Soybeans	Other	Total
REGION I						
South Atlantic	1	0	4269	5185		9454
Mississippi River	16	162146	950527	368153		1480826
Eastern Gulf	3	12548	19035	68225		99808
Total	20	174694	973831	441563		1590088
REGION II						
Canadian Lakes	4	20889	0	0		20889
U.S. Lakes	20	108929	142438	62539		313906
North Atlantic	3	16172	58836	12337		87345
South Atlantic	5	21201	294818	48033		364052
Total	32	167191	496092	122909		786192
REGION III						
North Texas	9	267743	91766	27447		386956
South Texas	3	29441	20	0		29461
Total	12	297184	91786	27447		416417
REGION V						
Columbia River	8	211917	0	605		212522
Puget Sound	3	47500	0	17		47517
California	5	13135	14755	295		28185
Total	16	272552	14755	917		288224
			Oats		8312	
			Barley		70015	
			Flaxseed		991	
			Sorghum		227008	
			Rye		0	
Totals	80	911621	1576464	592836	306326	3387247

*Excludes export rail shipments of wheat, corn, and soybeans from Region III, South Texas.

Source: Data provided by FGIS.

Table 36 shows what part of the total inspected exports (wheat, corn, and soybeans only) was comprised of corn in the various export areas. The area labeled "Other Region I" has a relatively low volume of exports even though corn exports in two of the years shown constitute a majority of that area's inspected exports. Region V also exported relatively little corn although there are indications that this is changing somewhat (table 36).

Table 36 shows the area designated as "Other Region II" actually exports a greater volume of corn than the Great Lakes. The export corn component of this area is also larger than the Great Lakes. The relative rate of increase of the corn component from year to year in that Region is much less than in the Great Lakes area. Under

"Other Region II," the corn component of exports was 69 percent of the total exports in 1975. In 1976, the corn component had increased to 73 percent, an increase of 4 percent. Comparing 1977 with 1976, the increase was 2 percent. In contrast, the Great Lakes and Gulf Coast areas have had wider variations than the other regions (discounting the relatively low-volume Region V and "Other Region I").

Increases in the corn components for the Great Lakes and the Gulf Coast in conjunction with greatly increased volumes of corn and corn dust handled by these areas may play a major part in the increase in explosion incidents at these locations. Other less visible factors are certainly involved.

Table 32.—Total inspected U.S. grain exports by regions (1,000 bushels) 1978 (first 6 months)*

	Number of export facilities	Wheat	Corn	Soybeans	Other	Total
REGION I						
South Atlantic	1	802	0	4051		4853
Mississippi River	16	58117	478831	261999		798947
Eastern Gulf	3	1594	65191	36485		103270
Total	20	60513	544022	302535		907070
REGION II						
Canadian Lakes	4	22675	0	0		22675
U.S. Lakes	20	61506	95768	37891		195165
North Atlantic	3	15378	45291	6749		67418
South Atlantic	5	18139	161816	31350		211305
Total	32	117698	302875	75990		496563
REGION III						
North Texas	8	199199	67127	10910		277236
South Texas	3	42845	0	0		42845
Total	11	242044	67127	10910		320081
REGION V						
Columbia River	8	153170	110	4		153284
Puget Sound	4	16224	42910	6		59140
California	5	19272	28571	251		48094
Total	17	188666	71591	261		260518
			Oats	1393		
			Barley	11225		
			Flaxseed	52		
			Sorghum	109949		
			Rye	0		
Totals	80	608921	985615	389696	122619	2106851

*Excludes export rail shipments of wheat, corn, and soybeans from Region III, South Texas.

Source: Data provided by FGIS.

Table 33.—Inspected U.S. grain exports

	1975	1976	1977	1978 (1st 6 mos.)
	(1,000 bu.)			
Wheat, corn & soybeans	2,904,754	3,283,685	3,080,921	1,984,232
Percent of change from 1975		13%	6%	
Total exports*	3,173,067	3,580,320	3,387,247	2,106,851
Percent change from 1975		13%	7%	
Wheat, corn & soybeans—Percent of Total	92%	92%	91%	94%

*Includes wheat, corn, soybeans, oats, barley, flaxseed, sorghum and rye exports only.

Table 34.—Inspected U.S. Grain exports passing through Gulf Coast ports, 1975-1977*

	1975	1976	1977
	(1,000 bu.)		
Region I	1,290,605	1,652,509	1,580,634
Region III	530,466	445,854	416,417
Totals	1,821,071	2,098,363	1,997,051
Percent change from 1975		15%	10%
Percent of exports	57%	59%	59%

*Wheat, corn, and soybeans only. Excludes export rail shipments to Mexico.

Table 35.—Inspected U.S. corn exports, 1975-1977 (1,000 bu.)

	1975	1976	1977
Gulf Coast			
Region I	781,737	1,052,043	969,562
Percent change from 1975		35%	24%
Region III	91,306	118,167	91,786
Percent change from 1975		29%	1%
Total Gulf Coast	873,043	1,170,210	1,061,348
Percent change from 1975		34%	22%
Percent of U.S. total corn exports	68%	68%	67%
Total Other Region I	8,123	14,336	4,269
Percent change from 1975		76%	-47%
Region II			
Lakes	112,833	155,149	142,438
Percent change from 1975		38%	26%
Atlantic	290,439	387,818	353,654
Percent change from 1975		34%	22%
Total Region II	403,272	542,967	496,092
Percent change from 1975		35%	23%
Total Region V	5,277	5,951	14,755
Percent change from 1975		13%	180%
Total U.S. corn exports	1,289,715	1,733,464	1,576,464
Percent change from 1975		34%	22%

7.2.3. Monitoring Export Handling System Use (System Loading)

Statistical tools exist which allow the identification of problem areas in the various segments of the grain handling system. These tools need further refinement before any degree of predictive accuracy can be developed. Table 37 presents yearly volume figures for inspected grain exports and the numbers of export handling facilities in applicable FGIS Regions. The last column in each yearly table presents figures which show the use of various segments of the export handling system. These figures are derived by dividing the volume of inspected grain exports (wheat, corn, and soybeans only) by the number of export handling facilities responsible for the volume handled and a scale factor.

In one sense these figures represent the average (mathematical) size of the facilities in each area shown. For instance, in 1975, each of the nine facilities then operating on the lower Mississippi River would have had to handle 130.2 million bushels of grain in order to yield the 1.17 billion bushels handled by that area. The 130.2 million bushels per year per facility is an average figure. As such it does not represent size distribution of the larger facilities.

In another sense, and the one intended, the "system loading" figure reflects relative usage

Table 36.—Comparison of U.S. inspected corn exports with total inspected exports of wheat, corn and soybeans by FGIS region 1975-1977 (1,000 bu.)

Area or FGIS Region	1975	1976	1977
Gulf Coast (Includes Region III & part of Region I)			
Corn exports	873,043	1,170,210	1,061,348
Total exports	1,821,071	2,098,363	1,997,051
Corn as percent of area total	48%	56%	53%
Other Region I			
Corn exports	8,123	14,336	4,269
Total exports	13,158	19,723	9,454
Corn as percent of area total	62%	73%	45%
Region II			
Great Lakes (Part of Region II)			
Corn exports	112,833	155,149	142,438
Total exports	302,471	272,539	313,906
Corn as percent of area total	37%	57%	45%
Other Region II			
Corn exports	290,439	387,818	353,654
Total exports	420,712	531,203	472,286
Corn as percent of area total	69%	73%	75%
Region II (Total)			
Corn exports	403,272	542,967	496,092
Total exports	723,183	803,742	786,192
Corn as percent of regional total	56%	68%	63%
Region V			
Corn exports	5,277	5,951	14,755
Total exports	347,342	361,857	288,224
Corn as percent of regional total	2%	2%	5%
Total U.S.			
Corn exports	1,289,715	1,733,464	1,576,464
Total exports	2,904,754	3,283,685	3,080,921
Corn as percent of U.S. total	44%	53%	51%

Note: All comparisons are based on inspected grain exports.

changes occurring in the export handling system. Large relative changes from year to year or from month to month in an area's total volume of grain handled (and in the corn/dust component) might result in increased risk of both fire and explosion. The use of a tool such as this to identify trends in export grain handling could be quite helpful in identifying possible problem areas.

It is suggested that such a monitoring system be refined somewhat by weighting each facility in an area according to the facility's normal total throughput, component thruputs, and normal handling speed. While the general growth of the system as

Table 37 —System loading based on inspected exports 1975-1978

Region & Area	1975***			1976**		
	Exports (1,000 bu) (a)	Facilities (b)	System Loading $\frac{a}{b(10^6)}$	Exports (1,000 bu) (a)	Facilities (b)	System Loading $\frac{a}{b(10^6)}$
Region I—total	1303761	13	100.3	1671332	13	128.6
South Atlantic	13156	1	13.2	18823	1	18.8
Mississippi River	1172065	9	130.2	1505991	9	167.3
Eastern Gulf	118540	3	39.5	146518	3	48.8
Region II — total*	723183	34	25.8	803742	33	28.8
Canadian Lakes	5688	5	1.6	19905	5	6.0
U.S. Lakes	302471	21	21.6	272539	20	20.4
North Atlantic	101082	3	33.7	108230	3	36.1
South Atlantic	313942	5	62.8	403068	5	80.6
Region III—total	530466	12	44.2	445854	12	37.2
North Texas	484627	9	53.8	404940	9	45.0
South Texas	45839	3	15.3	40914	3	13.6
Region V—total	347342	14	24.8	361857	14	25.8
Columbia River	218882	7	31.3	235315	7	33.6
Puget Sound	66850	3	22.3	78145	3	26.0
California	61610	4	15.4	48397	4	12.1
Region & Area	1977**			1978**		
	Exports (1,000 bu) (a)	Facilities (b)	System Loading $\frac{a}{b(10^6)}$	1st 6 mos. Exports (1,000 bu) (a)/2	Facilities (b)	Projected System Loading $\frac{a}{b(10^6)}$
Region I—total	1590088	20	79.5	907070	20	91.0
South Atlantic	9454	1	9.5	4853	1	9.7
Mississippi River	1480826	16	92.6	798947	16	99.9
Eastern Gulf	99808	3	33.3	103270	3	68.8
Region II — total*	786192	32	29.8	496563	32	37.8
Canadian Lakes	20889	4	7.8	22675	4	17.0
U.S. Lakes	313906	20	23.6	195165	20	29.2
North Atlantic	87345	3	29.1	67418	3	44.9
South Atlantic	364052	5	72.8	211305	5	84.5
Region III—total	416417	12	34.7	320081	11	58.2
North Texas	386956	9	43.0	277236	8	69.3
South Texas	29461	3	9.8	42845	3	28.6
Region V—total	288224	16	18.0	260518	17	30.6
Columbia River	212522	8	26.6	153284	8	38.3
Puget Sound	47517	3	15.8	59140	4	29.6
California	28185	5	5.6	48094	5	19.2

*Region II system loading figures are corrected to take into account the Great Lakes shipping season.

**Inspected wheat, corn and soybean exports only. (Excludes export rail shipments from Region III).

***Even though the pace of export inspections accelerated during the second 6 months of 1978, a conservative projection for 1978 in its entirety was obtained by doubling the first 6 months' totals.

a whole is understood, radical increases from this norm suggest that the system is approaching an actual handling limit.

7.2.4. Conclusions

The Task Force concludes the following:

- Massive increases in U.S. grain exports have created a stress situation in the export grain handling system. The volumes of grain actually handled are approaching the design handling limits of the system.

- A very limited number of elevators along the Gulf Coast handle 60 percent of inspected U.S. grain exports. This results from various production, marketing, transportation, and handling factors.

- Much of the increase in grain exports can be attributed to the increase in corn exports.

- About 68 percent of total U.S. corn exports have been handled by Gulf Coast elevators.

- The growth of both total grain and corn exports through the Gulf Coast elevators generally has exceeded the growth noted in the system as a whole.

- Because corn generates large amounts of dust during normal handling, large increase in the volume of corn and other grains handled results in increased amounts of dust available for ignition. This constitutes a significant hazard when the volumes of grain and dust actually handled are near the design handling capability of the grain handling system or any of its component parts.

- Existing analytical tools can be used to identify those trends in the grain handling system currently thought to increase fire and explosion hazards in grain handling facilities.

- Fires and explosions in grain handling facilities reduce the overall handling capability. When these occurrences and their deleterious effects are widespread in the handling system, an additional stress situation exists in the system as a whole. Other parts must take up the slack resulting from this dysfunction and handle larger volumes of grain.

7.2.5. Recommendations

The Task Force recommends the following:

- Monitor the U.S. handling system in order to identify possible trends affecting fire and explosion hazards.

- Collect and remove grain dust, particularly corn dust, from handling facilities.

- Prohibit reintroduction of this dust into the grain stream.

- Conduct research involving:

- Alternate and/or more equitable export grain distribution and handling systems, and

- Facility design and construction and operation of the grain handling system to minimize handling system dysfunction caused by fires and explosions.

7.3. COMPARISON OF U.S. AND FOREIGN GRAIN HANDLING

Because of current marketing techniques, grain production requires grain storage and handling facilities. Other countries produce substantial amounts of grain, but preliminary reports by the USDA's agricultural attaches indicate that many grain producing countries have experienced fewer explosions than the United States. Comparison of the national experience of the United States, Australia, and South Africa revealed differences both in the grain handling system and in the incidence of fires and explosions.

This section compares grain handling information for the United States with similar data for Australia and South Africa. The information for Australia was obtained during a 2-week tour of Australian grain handling facilities and by review of the Australian contribution to the International Symposium on Grain Elevator Explosions (ref. 31). The information for South Africa was obtained through a review of that country's formal presentation at the International Symposium (ref. 32).

7.3.1. Facilities

The U.S. grain handling system is comprised of over 15,000 facilities which can store over 6 billion bushels of grain at one time. There are fewer handling facilities, less storage capacity, and relatively smaller handling, storage, and processing systems in Australia and South Africa. Australia's handling system has 951 facilities which can store 121,931,000 bushels. South Africa's handling system has 200 facilities which can store 230,000,000 bushels of grain.

The major grain produced in the United States is corn (162,000,000 metric tons in 1977) and this is triple the production of either wheat (55,133,000 metric tons) or soybeans (46,700,000 metric tons). Barley ranks fourth with 9,100,000 metric tons.

Australia's major crop is wheat (9,200,000 metric tons in 1977) followed by 2,300,000 metric tons of barley and 136,000 metric tons of corn.

South Africa, like the United States, produces more corn than any other grain (10,000,000 metric tons in 1977). Five times more corn is produced than second-ranking wheat (2,000,000 metric tons in 1977). In 1977 South African barley and soybeans ranked third and fourth in amount of grain production with 63,000 and 28,000 metric tons, respectively.

7.3.2. Elevator Construction

Most grain elevators in the United States have concrete headhouses although some older facilities are constructed of wood. In contrast, concrete headhouses generally are not constructed in Australia.

Australian grain handling facilities are, for the most part, constructed with nonflammable materials. These facilities are designed for pressure relief by venting with light wall-cladding panels. These panels are designed to blow out in the event of an explosion. Elevators in Australia generally have larger work areas than do U.S. facilities.

South African headhouses are normally constructed between four bins and clad with sheeting. Many of South Africa's older elevators have fully enclosed gantries as do U.S. facilities. Newer elevators are built with grating for floors.

7.3.3. Australian Equipment

Australian grain elevators utilize a number of safety devices on their equipment which are not generally found in U.S. elevators.

This section outlines a number of these innovations considered significant to hazard prevention.

Australian elevators are able to monitor belt movement by using a speed response switch. When the switch is tripped, the conveyor stops and cannot start again until the problem is solved.

Rubber-coated cotton web belts are used exclusively. Belts are joined by vulcanizing instead of by metal joiners to minimize sparks caused by contact with idlers. All conveyors, including vertical bucket elevators, are fitted with belt tension and pulleys to eliminate the likelihood of belt slippage or bucket contact with elevator casings. Belt runoff detectors are fitted to all belts.

In Australian elevators, testing for static electricity buildup is a part of the regular routine of safety checking. The entire electrical installation including all metal parts is effectively grounded.

Australian elevators make only limited use of grain dryers. The moisture content of grain received is usually 12 percent or less so that in most cases drying is not necessary. Gas fired or other combustion appliances are not used for grain drying.

Cleaners are not used in large elevators in Australia because dust control systems are utilized for this purpose.

In South Africa corn and wheat are delivered to elevators straight from combines. Wheat is cleaned before it is binned. Corn is stored before it is cleaned but is cleaned on reclaim.

7.3.4. Operations

Australian elevators may store grain for as long as 9 months before shipping. Preventive maintenance rather than emergency maintenance is the rule.

South African elevators normally operate from 0660 to 1800 hours during the day. Essentially used as storage facilities, they are seldom filled and emptied more than once during a harvest season.

In the United States many terminals and export elevators operate 24 hours each day. During harvest periods this is also common in many smaller facilities. Total facility thruput will usually represent many complete inventory turnovers. Emergency maintenance operations are common.

In comparison with Australia and South Africa, normal operations and facility use in the United States are significantly different.

Unlike the foreign elevators, the U.S. elevators' total thruput normally represents many consecutive storage filling and emptying operations. Grain storage is the major function in most Australian and South African facilities. In the United States, handling is the major function.

These two countries would also appear to differ from the United States in the emphasis they place on equipment maintenance, but this may result from the greater operational demands placed on U.S. facilities.

7.3.5. Dust Control and Housekeeping

The Australian situation with regard to dust control and housekeeping can be characterized as follows:

All dust control systems are designed using the static pressure balance method. They are interlocked with facility handling and processing equipment and with any other dust control systems used in the facility. This equipment cannot

be operated unless the dust control system is in operation.

Dust control systems use fans with large horsepower ratings. This results in high cubic feet per minute values. Both velocity air-flows within systems and the total volumes of air handled are large.

Because high air velocities are used, dust collection hoods are relatively small. Hoods are located at major transfer points within facilities and at extremely dusty pieces of equipment such as trippers which are completely enclosed.

Cyclone separators are used as precleaning devices on most bag filter-type dust control systems. By removing larger particles, abrasion in the system, and particularly in filter units, is minimized. Main exhaust fans for dust control systems are commonly located on the clean air side of filters. This reduces fan and motor wear and helps ensure trouble-free operation.

Because of the high-power dust control systems in use, grain cleaners or scalpers are unnecessary. In effect, each pickup hood is used as a cleaner.

Regarding housekeeping, a general daily clean-up is scheduled and implemented. Facilities are washed down with water once each year. Periodic compressed air blowdown is an integral part of the housekeeping process.

Certain other practices are also common in many Australian grain handling facilities. Storage tanks and bins are not cross vented. Upper and lower scale garners are intervened through a 36-inch pipe. Aspiration is provided at the upper garner. The scale itself is intervened with the upper garner through another 36-inch diameter vent pipe.

When compared to Australia, U.S. dust control and housekeeping practices in handling facilities are less extensive. Design criteria for dust control systems as well as the operation of these systems is not standardized. In general, dust control measures in the United States are not as effective as those in Australia, and housekeeping in the United States is apparently given a lower priority than in Australia.

7.3.6. Number of Explosions Experienced

The U.S. grain handling system has experienced many more grain dust explosions than either Australia or South Africa. Many of the explosions that have occurred in the United States have resulted in the destruction of facilities and in hundreds of deaths and injuries. At least 250 grain dust explosions have occurred in U.S. grain handling facilities. There was one minor explosion in

an Australian grain handling facility in the last 60 years and three minor explosions in South Africa.

7.3.7. Fire Incidents

It is estimated that the United States has averaged 2,700 fires per year in grain handling and storage facilities for the 21 years from 1958 through 1978. In contrast, information on the fire experience in Australia reveals an average of only six fires per year over the past 10 years. Information on the number of fires in South African grain storage and handling facilities was not available.

7.3.8. Conclusions

Facilities engaged in grain handling and marketing and in storage and processing functions comprise the U.S. grain handling system. It is characterized by more storage and handling facilities and larger volumes of grain to merchandise and handle than comparable systems in Australia or South Africa.

- Australian grain exports consist almost exclusively of wheat. The United States exports primarily corn as well as wheat and soybeans.

- Problems encountered in the U.S. handling system are different in both size and severity from those in either Australia or South Africa. They result from a combination of many different factors, but are most intimately related to the size and age of the U.S. handling system and to the volumes of grain it must handle.

- In Australia, rigorous application of design, construction, dust control, maintenance, housekeeping, safety and other fire/explosion prevention measures has resulted in a low number of fires and explosions. Their relative success in comparison to the United States may partly depend on the smaller number of facilities, the smaller volumes of grain handled, the types of grain handled, and the relatively limited time Australia has been involved in bulk grain handling.

7.3.9. Recommendations

- Consider the application of those safety features and techniques used by the Australians in the construction of new U.S. grain handling facilities.

- Consider the application of those safety techniques which have proved successful in Australia in the retrofitting or renovating of U.S. grain handling facilities.

7.4. RELATIVE HUMIDITY—A PILOT STUDY

FGIS instructions have cited low levels of atmospheric R.H. when coupled with excessive dust as constituting unduly hazardous conditions in grain handling facilities. From April through December 1978, this has been the determining factor for 32 evacuations of export elevators by FGIS employees.

This pilot study was undertaken to identify any positive correlation between atmospheric R.H. and recorded instances of grain elevator dust explosions. If any correlation were found, parameters could be defined for levels of R.H. within which there have been instances of dust explosions. Until a more comprehensive study is completed this "hazardous" range of R.H. could be used in implementing FGIS safety instructions.

7.4.1. Development of Data

The major criteria used to develop the incident list in this study were that there be information regarding the location of the facility, the date and time of the incident, and that the incident location be relatively close to a NOAA reporting station. Twenty-four recent incidents, in general, met these criteria and were selected for study. These incidents are listed in table 38.

For each of the incidents R.H. and temperature readings taken at approximately 3-hour intervals were obtained from NOAA. Temperature was deleted from the study since consistent data for each incident were not available. Except for incidents 10 and 24, R.H. data covered the day of the explosion as well as the 7 days preceding the explosion. Incident 10 data did not include R.H. readings for the seventh day prior to the explosion. Incident 24 data did not include readings for the day of the explosion. Data were not collected nor recorded within any of the elevators.

On the basis of R.H. alone two analyses were performed. Interpolated R.H. values at the time of each incident were extracted and compared. Computed daily R.H.'s were graphed against time for the 7 days preceding each incident and the day of the incident.

7.4.2. Data and Findings

Table 39 contains general information regarding each incident. As shown, distances separating NOAA reporting stations from incident sites varied widely from about 5 miles to more than 100 miles.

In table 39, columns 2 through 9 present average daily R.H.'s for 7 days preceding an incident and for the day of the incident. This material is presented graphically in figure 14. Columns 10 and 11 of table 39 show the time of occurrence for each incident and the interpolated R.H. at that time (except for incident 24). Notations in column 11 also indicate the direction of R.H. change. Generally, minor R.H. changes of 1 percent or less are shown as "NC" or "No Change." The interpolated R.H.'s at the time of each incident are also shown graphically along with the daily R.H.'s in figure 14.

As shown in table 39, column 11, R.H. values at the time of each incident ranged from 12 percent to 100 percent. The computed arithmetic mean is approximately 53 percent. On the basis of R.H. at the time of the incident, there is no apparent grouping of the data points. Since there is no evident correlation in R.H.'s at the times of the incidents, R.H. at the time of a dust explosion probably can be discounted as a causal or contributory factor in the 23 incidents for which data is available.

This finding assumes that R.H. as recorded at the NOAA reporting station accurately reflects the R.H. at the incident site. This has not been demonstrated empirically and, considering the distances separating some of the NOAA reporting stations from the incident sites, the validity of this assumption is questionable.

Still, this study indicates a possible relationship between R.H. and grain dust explosions. Examining figure 14 further, it is evident that while the graphs do not assume a common form, all of the graphs exhibit average R.H.'s at some time during the 8-day period which are markedly lower than the 8-day mean for each incident. Comparison of columns 12 and 13 of table 39 demonstrates this.

Column 14 shows the day on which the minimum average R.H. occurred. Column 15 shows the difference between the 8-day mean and the minimum for each incident. The pronounced drop in daily R.H. during the period preceding the explosion incident appears significant. Although a lack of adequately documented explosion incidents precludes any definitive statement, a certain amount of speculation seems justified.

7.4.3. Discussion and Theory

It is well documented that grain and grain products adsorb or desorb moisture in the process of reaching a moisture equilibrium state with respect to the R.H. of the surrounding atmosphere. This moisture - R.H., or vapor pressure, equilibrium

Table 38.—Twenty-four explosion incidents — data

	Facility name and location	Date of incident	Duration of study	NOAA reporting station	Approximate distance from incident site (miles)
A	International Multi-Foods Davenport, IA	5/23/75	5/16-23/75	Moline, IL	7
B	Far-Mar-Co Lincoln, NE	9/25/75	9/18-25/75	Lincoln, NE (AFS)	5
C	Michigan Farm Bureau, Inc. Zilwaukee, MI	1/22/76	1/15-22/77	Flint, MI	40
D	Goodpasture Galena Park, TX	2/22/76	2/15-22/77	Houston, TX	7
E	Kokomo Grain Kokomo, IN	2/25/76	2/18-25/76	Indianapolis, IN	40
F	New Era Milling Arkansas City, KS	5/23/76	5/16-23/76	Wichita, KS (AFB)	45
G	Fairfax Grain & Supply Coop. Fairfax, MN	6/21/76	6/14-21/76	Rochester, MN	115
H	Central Soya Hastings, NE	8/18/76	8/11-18/76	Grand Island, NE	20
I	Delavan Farmers Elevator Co. Delavan, MN	8/19/76	8/12-19/76	Rochester, MN	75
J	Ohio Grain Mechanicsburg, OH	11/6/76	10/31/76— 11/6/76	Columbus, OH (Port Columbus)	35
K	McAlester Milling Co. McAlester, OK	12/20/76	12/13-20/76	McAlester, OK	10
L	Burdick Grain Minneapolis, MN	5/11/77	5/4-11/77	Minneapolis, MN	10
M	Indiana Farm Bureau Cooperative, Inc. Logansport, IN	5/25/77	5/18-25/77	Indianapolis, IN	50
N	Garvey Grain Chicago, IL	8/4/77	7/28/77— 8/4/77	Chicago, IL (O'Hare Airport)	16
O	Producers Grain Corporation Corpus Christi, TX	9/13/77	9/6-13/77	Corpus Christi, TX	10
P	Petersburg Coop. Crain Co. Petersburg, TX	10/26/77	10/18-25/77	Lubbock, TX	25
Q	Kimball Milling Durant, OK	11/30/77	11/23-30/77	Ardmore, OK	40
R	Simpson Grain Co. Woodward, OK	12/7/77	11/30/77— 12/7/77	Oklahoma City, OK	20
S	Sunshine Mills Tupelo, MS	12/22/77	12/15-21/77	Meridian, MS	120
T	Continental Grain Co. Westwego, LA	12/22/77	12/15-22/77	New Orleans, LA	5
U	Farmers Export Co. Galveston, TX	12/28/77	12/21-28/77	Houston, TX	30

Table 38.—Twenty-four explosion incidents — data — Continued

	Facility name and location	Date of incident	Duration of study	NOAA reporting station	Approximate distance from incident site (miles)
V	Desert Gold Feed Co. Liberty, MO	1/19/78	1/12-19/78	Kansas City, MO	5
W	Crescent Cooperative Assoc. Crescent, OK	3/9/78	3/2-9/78	Oklahoma City, OK	25
X	Tabor Mills N. Kansas City, MO	3/16/78	3/9-15/78	Kansas City, MO	10

relationship is commonly described by the use of a water sorption isotherm. Such isotherms for grain and its products are generally S-shaped curves which describe the equilibrium relationship at a specified temperature. Atmospheric R.H. or vapor pressure is plotted along one axis while the moisture content of the grain is plotted along the other.

A water sorption isotherm may be either an adsorption or a desorption isotherm; this depends on whether the sample of grain starts off at a moisture content greater than or less than the grain's equilibrium moisture content. In the first case where the beginning moisture content is greater than the equilibrium moisture content, the sample would lose water (desorption) in order to reach the equilibrium state. Where the beginning moisture content is less than the equilibrium moisture content, the sample would have to gain water (adsorption) in order to reach its equilibrium state.

Adsorption and desorption isotherms for the same grain or grain product usually are not the same. Desorption isotherms for grain and grain products generally are displaced a marked distance to the left of the adsorption isotherm (Ref. 33). Different samples of the same material in equilibrium states with the same atmosphere can have different moisture contents depending on whether the sample lost or gained water in order to reach the equilibrium state. This phenomenon of differing equilibrium moisture contents, dependent on the direction from which equilibrium is approached, is known as the hysteresis effect (ref. 33).

There is another type of hysteresis effect, analogous to a hysteresis effect noted in electrical circuits, which manifests itself when grain or grain dust is in the process of attaining hygroscopic equilibrium. This is the measurable length of time which is required for the completion of this process. If it is assumed that the moisture content of a sample differs from its equilibrium moisture content at any given time, it requires some measur-

able period of time to achieve the hygroscopic equilibrium state.

In the reference cited above, there is a brief description of this type of time-related hysteresis, although the effect is not named as such. While discussing possible inhibiting factors in the sorption of water by proteins, Hlynka and Robinson cite unspecified previous work, which yielded results of 6 to 8 days to reach adsorption equilibrium and over 18 days to reach desorption equilibrium (ref. 33). It is assumed that these figures also refer to the sorption of water by protein-based systems but the exact substance is unknown. It is the time-related hysteresis effect which in part is thought to explain the significance of the recorded drop in the daily average R.H.'s at some time preceding the explosion incidents.

Static dust exists in large quantities in most grain elevators. Dust is present mixed with the grain in storage or being handled. As a result of handling it is both generated and dispersed into the air inside the facility. It settles on every surface within the facility. In some cases it may accumulate to a depth of several inches during the course of normal operations.

At some previous time this dust will have had a moisture content approximating the large mass of grain from which it originated. Large masses of grain would tend to have a moderating influence on the hygroscopic equilibrium changes of their constituent parts (discounting the possible effects of infestation, moisture translocation, condensation on the walls of storage bins, leaky roofs, etc.). When the dust is removed from the grain and deposited in the elevator, the change moderating effect of that grain is also removed. The dust deposits now comprise a hygroscopic system within the facility distinct from the grain which is there.

The moisture content of these dust deposits within the facility will change continually as the hygroscopic equilibrium reacts to changes in atmospheric temperature and R.H. Some work has

Table 39. — Data on relative humidity and explosion incidents

Column No. 1	average daily relative humidity (percentage)													10	11	12	13	14	15	
No.	Facility and location	7 days preceding explosion — E = day of explosion													Time of incident (hrs. 1st)	Relative humidity at time of incident	8-day mean relative humidity	Minimum daily average relative humidity during 8-day period	Day when minimum occurred	Difference: 8-day Mean minus minimum
		-7	-6	-5	-4	-3	-2	-1	E											
A.	International Multi-Foods Davenport, IA	68	58	47	53	67	82	72	64	1215	51↓	64	47	-5	17					
B.	Far-Mar-Co, Inc. Lincoln, NE	69	53	65	60	63	59	70	65	1630	33↑	63	53	-6	10					
C.	Michigan Farm Bureau Inc. Zitwaukee, MI	73	71	63	64	68	76	76	79	1126	72↓	71	63	-5	8					
D.	Goodpasture Galena Park, TX	78	76	82	50	65	81	57	41	1300	24↓	66	50	-4	16					
E.	Kokomo Grain Kokomo, IN	89	82	67	78	77	68	50	43	1554	34↓	69	50	-1	19					
F.	New Era Milling Arkansas City, KS	69	55	55	58	65	69	78	70	0800	77↓	65	55	-5	10					
G.	Fairfax Grain & Supply Coop Fairfax, MN	66	67	58	56	70	62	48	52	1100	33↓	60	48	-1	28					
H.	Central Soya Hastings, NE	60	55	58	78	83	62	51	50	1000	87↑	62	51	-1	11					
I.	Delavan Farmers Elevator Delavan, MN	63	67	74	61	69	76	75	68	0800	70↓	69	61	-4	8					
J.	Ohio Grain Mechanicsburg, OH		90	69	60	44	65	69	60	2215	66	65*	44	-3	11					
K.	McAlester Milling Co. McAlester, OK	68	71	67	41	33	57	69	49	1545	27↓	57	33	-3	16					
L.	Burdick Grain Minneapolis, MN	85	60	50	45	49	35	43	40	1730	12↑	51	35	-2	16					
M.	Indiana Farm Bureau Cooperative, Inc. Logansport, IN	64	65	67	66	72	71	74	70	1829	44↓	69	64	-7	5					
N.	Garvey Grain Chicago, IL	59	63	62	56	52	66	66	70	0530	73↓	62	52	-3	10					
O.	Producers Grain Corporation Corpus Christi, TX	69	65	80	78	75	75	74	74	1315	51↑	74	65	-6	9					
P.	Petersburg Coop. Grain Co. Petersburg, TX	41	45	47	58	82	76	64	55	1430	22↓	58	41	-7	17					

Table 39. — Data on relative humidity and explosion incidents (Con't)

Column No. 1	average daily relative humidity (percentage)														
	7 days preceding explosion — E = day of explosion														
No.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Facility and location	-7	-6	-5	-4	-3	-2	-1	E	Time of incident (hrs, 1st)	Relative humidity at time of incident	8-day mean relative humidity	Minimum daily average relative humidity during 8-day period	Day when minimum occurred	Difference: 8-day Mean minus minimum	
Q. Kimball Milling Durant, OK	74	86	58	55	77	55	77	81++	1930	82 NC	69	55	-4	14	
R. Simpson Grain Company Woodward, OK	70	61	58	41	74	79	53	52	1430	36†	61	41	-4	20	
S. Sunshine Mills Tupelo, MS	80	79	73	58	70	57	62	65	1130	44↓	68	58	-4	10	
T. Continental Grain Co. Westwego, LA	90	91	72	58	81	68	51	63	0907	64↓	72	51	-1	21	
U. Farmers Export Co. Galveston, TX	44	57	74	78	64	63	57	86	2030	100 NC	65	44	-7	21	
V. Desert Gold Feed Co. Liberty, MO	75	82	76	79	72	60	77	77	2133	76↓	74	60	-2	14	
W. Crescent Cooperative Assoc. Crescent, OK	86	65	58	50	58	87	77	60	1530	35	77	50	-4	27	
X. Tabor Mills N. Kansas City, MO	59	50	81	79	85	76	74	74	1600		72	50	-6	22	
Arithmetic mean	70+	67	65	61	67	68	65	62+		53	66	51	4		
↑ Increasing ↓ Decreasing NC No Change															
* 7 Days Only															

* 7 Days Only

+ 23 Incidents only

++ Two minimum's of equal value occur.

↑ Increasing

↓ Decreasing

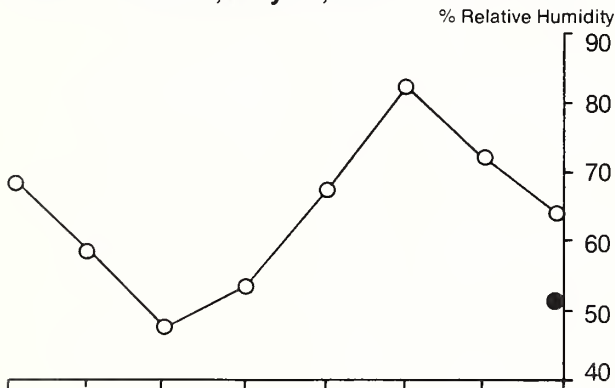
NC No Change

Figure 14

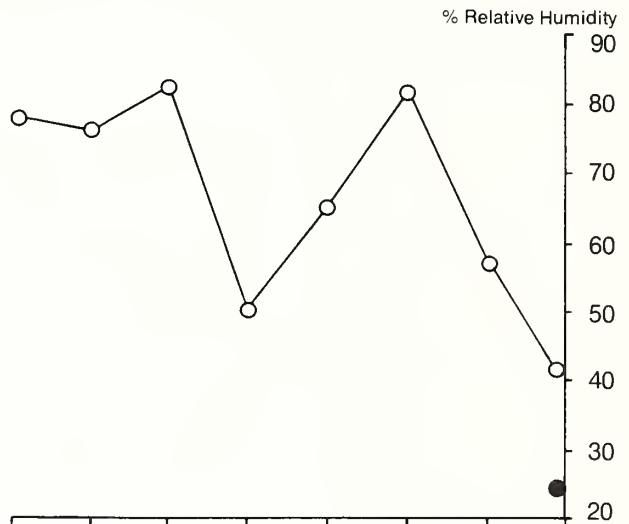
Relative Humidity and Explosion Incidents

○ Daily average relative humidity
● Humidity at time of explosion

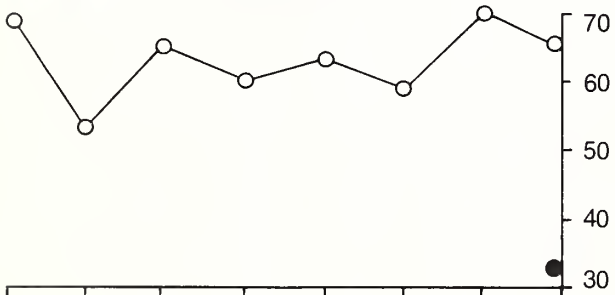
A International Multifoods, Davenport, Iowa
12:15 P.M., May 23, 1975



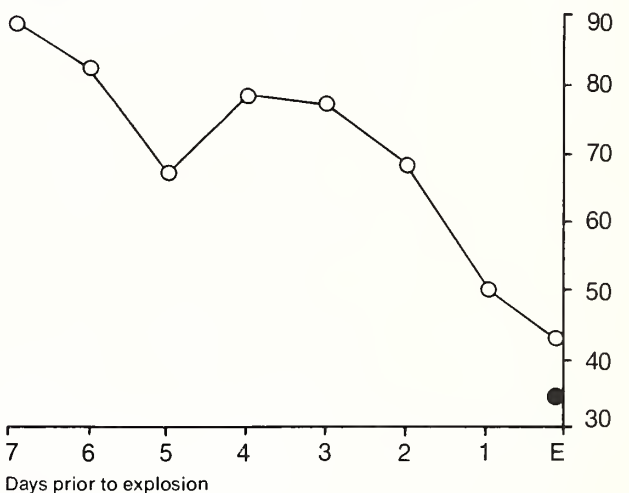
D Goodpasture, Houston (Galena Park), Texas
1:00 P.M., February 22, 1976



B Far-Mar-Co, Inc., Lincoln, Nebraska
4:30 P.M., September 25, 1975



E Kokomo Grain, Kokomo, Indiana
3:54 P.M., February 25, 1976



C Michigan Farm Bureau, Inc.
Zilwaukee, Michigan
11:26 A.M., January 22, 1976

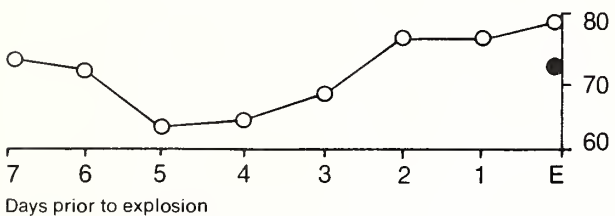
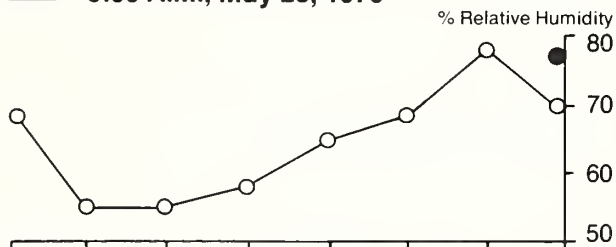


Figure 14 Relative Humidity and Explosion Incidents

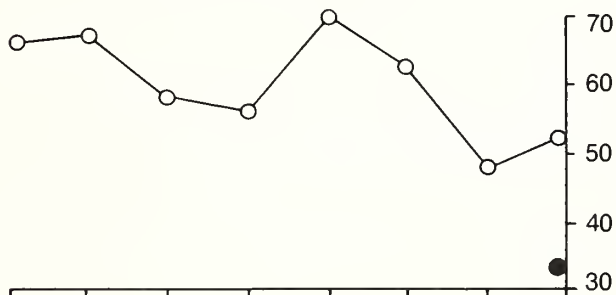
Figure 14 (continued)

Relative Humidity and Explosion Incidents

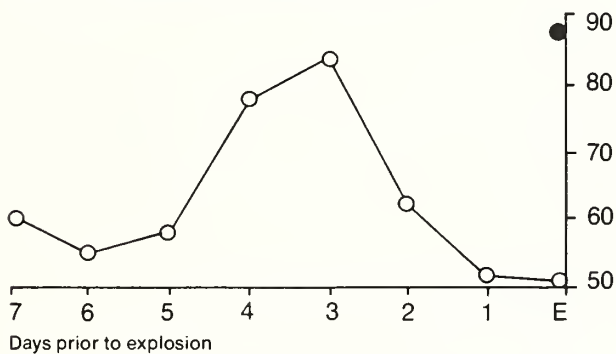
F New Era Milling, Arkansas City, Kansas
8:00 A.M., May 23, 1976



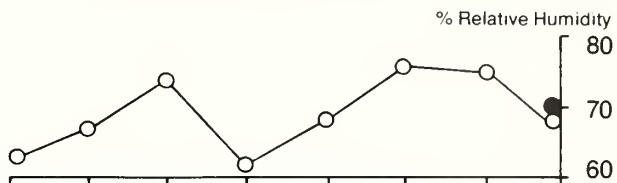
G Fairfax Grain and Supply Cooperative
Fairfax, Minnesota
11:00 A.M., June 21, 1976



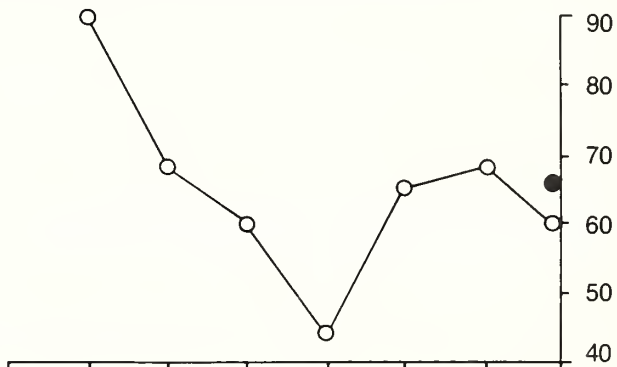
H Central Soya, Hastings, Nebraska
10:00 A.M., August 18, 1976



I Delavan Farmers Elevator Company
Delavan, Minnesota
8:00 A.M., August 19, 1976



J Ohio Grain, Mechanicsburg, Ohio
10:15 P.M., November 6, 1976



K McAlester Milling Company
McAlester, Oklahoma
3:45 P.M., December 20, 1976

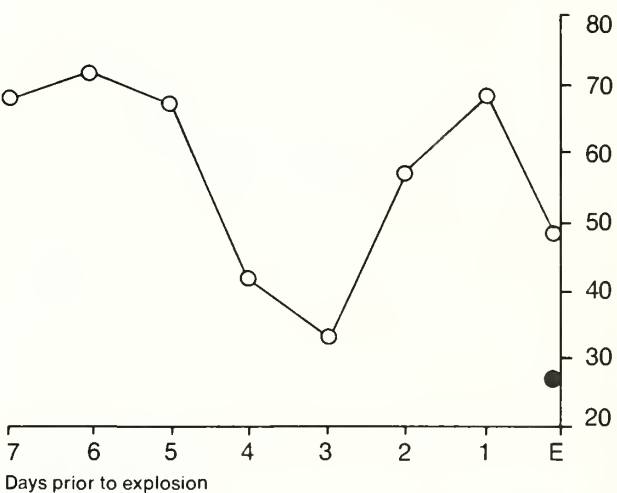
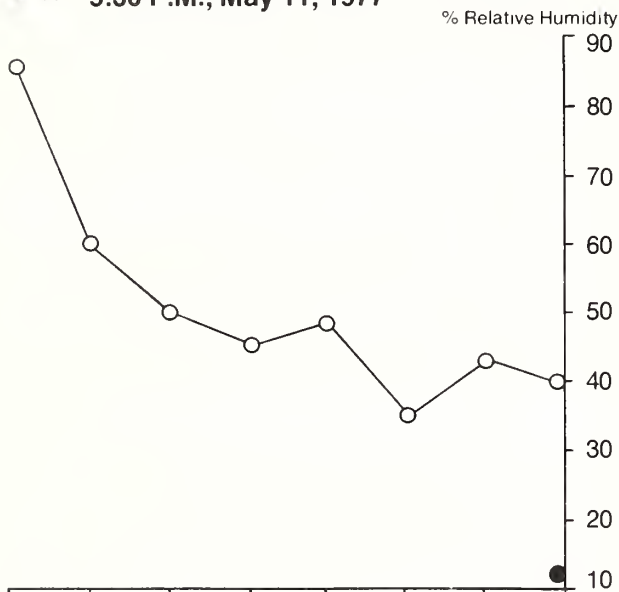


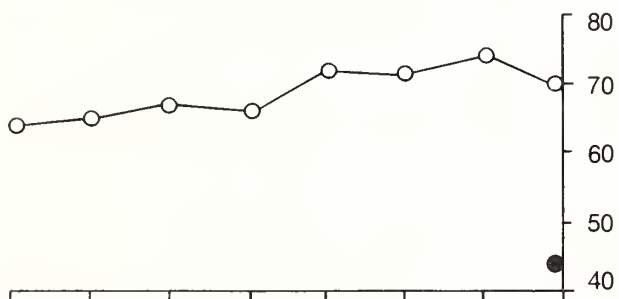
Figure 14 (continued)

Relative Humidity and Explosion Incidents

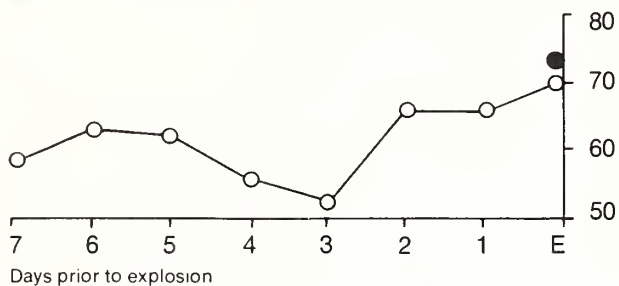
L Burdick Grain, Minneapolis, Minnesota
5:30 P.M., May 11, 1977



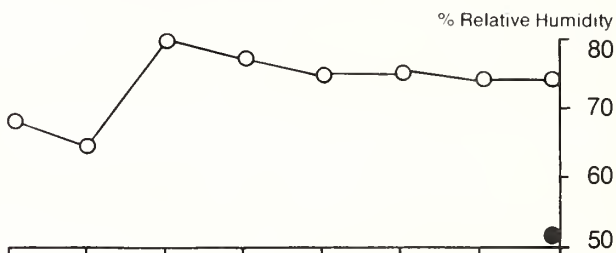
M Indiana Farm Bureau Cooperative Association, Inc., Logansport, Indiana
6:29 P.M., May 25, 1977



N Garvey Grain, Chicago, Illinois
5:30 A.M., August 4, 1977



O Producers Grain Corporation
Corpus Christi, Texas
1:15 P.M., September 13, 1977



P Petersburg Co-op Grain Company
Petersburg, Texas
2:30 P.M., October 26, 1977

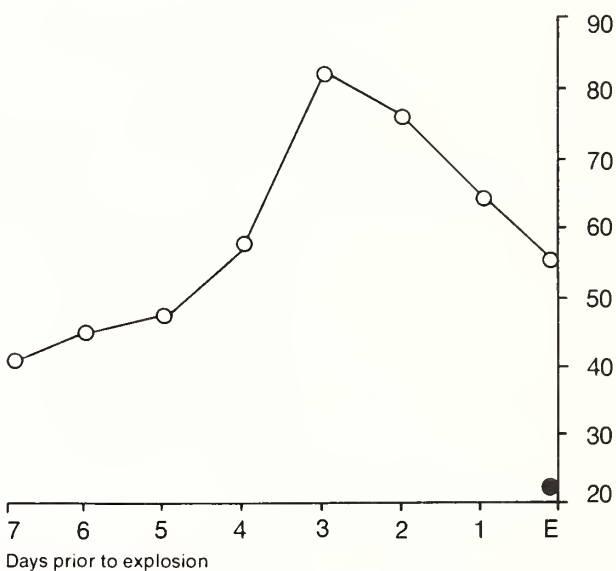
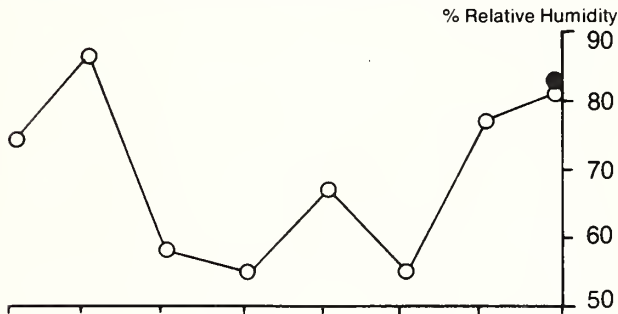


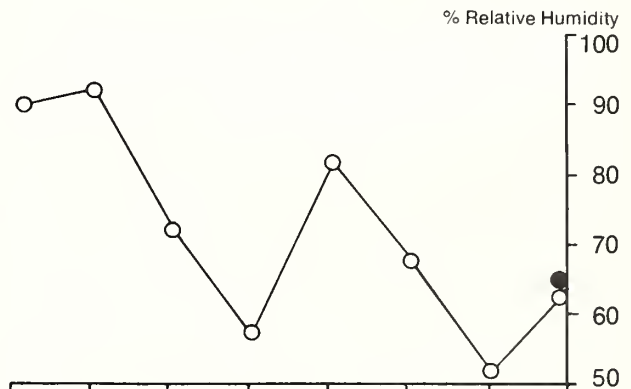
Figure 14 (continued)

Relative Humidity and Explosion Incidents

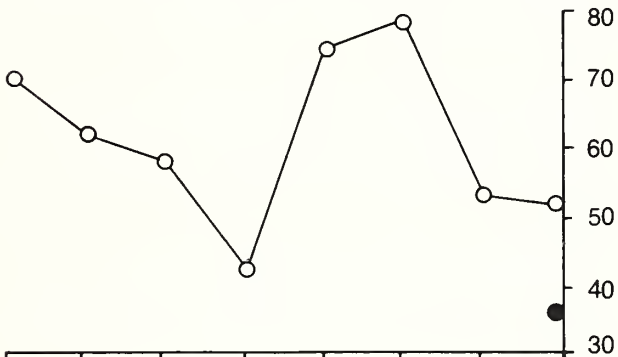
Q Kimball Milling, Durant, Oklahoma
7:30 P.M., November 30, 1977



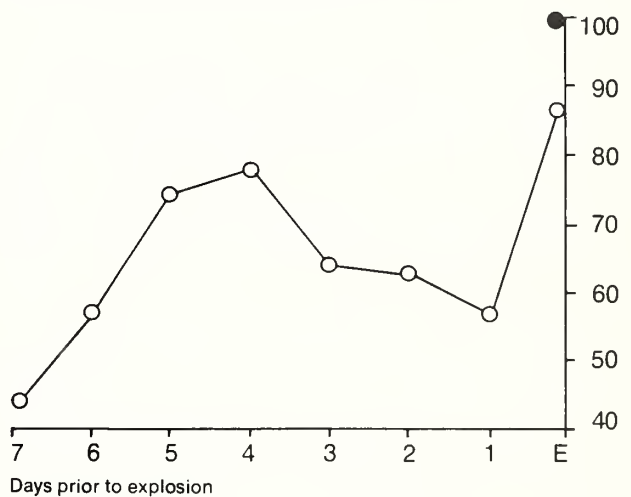
T Continental Grain Company
New Orleans (Westwego), Louisiana
9:07 A.M., December 22, 1977



R Simpson Grain Company
Woodward, Oklahoma
2:30 P.M., December 7, 1977



U Farmers Export Company
Galveston, Texas
8:30 P.M., December 28, 1977



S Sunshine Mills, Tupelo, Mississippi
11:30 A.M., December 22, 1977

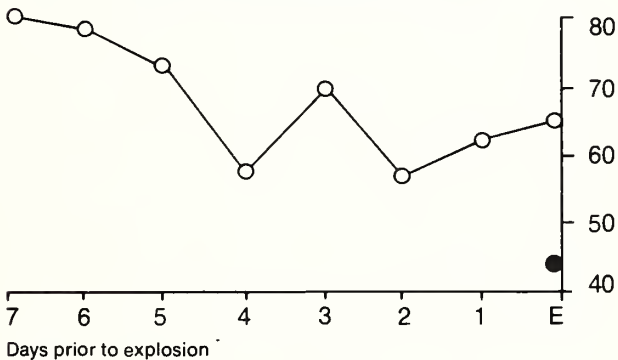
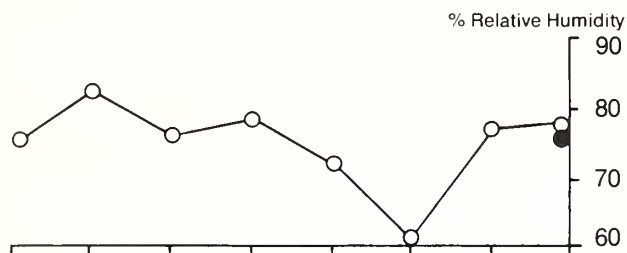


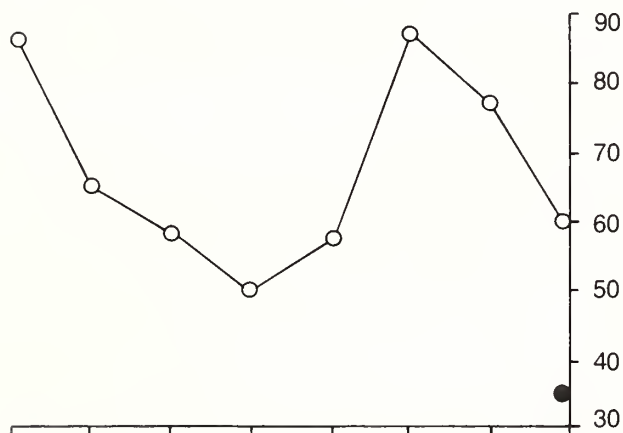
Figure 14 (continued)

Relative Humidity and Explosion Incidents

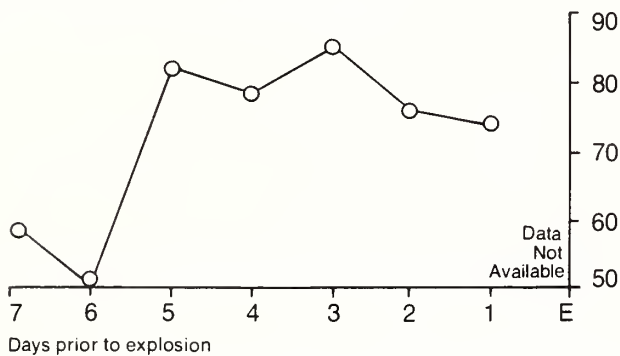
V Desert Gold Feed Company
Liberty, Missouri
9:33 P.M., January 19, 1978



W Crescent Cooperative Association
Crescent, Oklahoma
3:30 P.M., March 9, 1978



X Tabor Mills, North Kansas City, Missouri
4:00 P.M., March 15, 1978



been done in the sorption rates of various substances and the time periods required to reach sorption equilibria. The problem is that no model now exists which adequately describes the hygroscopic processes at work on the dust deposits inside a grain handling facility. While a great deal is known in general, very little is actually known about specifics. The time required for these processes and even the magnitude of the hygroscopic changes are unknown. What other mechanisms are involved? What effect does air movement have within the facility? What of the effects of packing or of moisture translocation because of successive heating and cooling in dust deposits? All of these could be important factors affecting hygroscopic equilibrium changes in dust deposits.

Based on the admittedly sketchy results obtained in this pilot study, a link does seem possible between the water sorption equilibrium changes of dust deposits and recorded dust explosion incidents. If at any given time there are dust deposits in a grain handling facility, because of time-related hysteresis, the moisture content of these deposits should reflect atmospheric R.H. conditions at some previous time. If the previous conditions were drier, the dust deposits would also be drier and this might present an increased opportunity for ignition.

At the time of each explosion the moisture content of the dust deposits in the facility is believed to represent the lower R.H. conditions which occurred at some previous time before the incident.

Column 14 of table 39 lists the day when a minimum daily average R.H. was recorded for each incident during the 8 days of the study.

The arithmetic mean was computed as approximately the fourth day prior to the incident. When comparing this mean with the results of each incident, the deviations are quite large. The introduction of secondary minimums decreases the overall deviation somewhat, but there is yet another possible explanation of this deviation. The equilibrium moisture content of a sample of dust depends on the direction from which equilibrium is approached. This also applies to the rate at which the phenomenon proceeds. Stated another way, the dust moisture content and the rate at which it proceeds toward hygroscopic equilibrium depends, in part, on the past history of that dust. Different samples of similar dust can react differently to the same stimuli depending on how the

dust and probably the grain from which it originated had been stored and handled.

Table 39, column 15, contains figures showing the differences between the 8-day mean R.H. and the minimum daily average R.H. recorded for each incident (column 13 subtracted from column 12). These differences were all positive and ranged from a low of 5 percent to a high of 28 percent R.H.. Holding all other factors constant, these positive differences could be interpreted as indicators showing relative degrees and rates of dust deposit desorption. If the 8-day mean R.H. is considered as the status quo and a reflection of the general equilibrium moisture content of dust deposits in the facility, then a lower R.H. such as those noted should indicate a tendency for the dust to lose water in an amount and at a rate proportional to the degree of difference in the R.H.'s.

If this hygroscopic hysteresis exists and can be documented by other studies, grain handlers should use extra caution following periods during which average daily R.H. is reduced. Specifically, the reduction of ignition sources during these periods is felt to be especially important.

7.4.4. Conclusions

Based on this pilot study, the Task Force concludes the following:

- Instantaneous R.H. (at the time of an explosion incident) does not appear to be either a causal or a contributory factor in grain dust explosions. A possible exception to this general proposition is low R.H. levels as related to electrostatic discharge types of ignition sources.
- Low average daily R.H. levels, in comparison with the norm for a period of 1 week, may result in a delayed reduction in the moisture content of static dust deposits commonly found in grain handling facilities. Drier dust reduces the energy required to ignite the dust, thus effecting an increase in the number of possible ignition sources having the requisite level of ignition energy.
- The parameters and mechanisms that may be involved in the possible relationship between R.H. and grain dust fires and explosions are not clearly defined.
- Additional research is needed.

7.4.5. Recommendations

The Task Force recommends the following:

- Perform additional research on the effects of R.H. as it is related to fire/explosion phenomena. This research should include:

- (1) Expanded statistical analysis of explosion incidents with regard to R.H.

- (2) Laboratory determination of the major processes and variables involved in grain and grain dust water sorption phenomena.
- (3) Laboratory and *in situ* quantification of this process.
- (4) *In situ* determination of the rate at which the sorption phenomenon proceeds and the resulting effects on ignition energy requirements.

LIST OF APPENDIXES

- A. Explosion Incidents, 1958-1978
- B. Explosion Questionnaires
- C. Grain Dust Explosions - Data (Samples of 15 and 66)
- D. Export Elevator Survey Questionnaires
- E. Export Elevator Survey — Data Summary
- F. Dust Survey Questionnaires
- G. Dust Survey — Data
- H. Guidelines for Safety Operations Plans
- I. FGIS Safety Instruction 370-3
- J. Numbers of Facilities
- K. OSHA-USDA; Non-recirculation of Dust
- L. FGIS Administrator; Non-recirculation of Dust
- M. OSHA General Industry Standards (Summary)
- N. OSHA Memo; "Information on Grain Elevator Inspections."
- O. SEA Program Review Report
- P. Summary of Other Standards Referenced in NFPA No. 61-B

Appendix A

Table 40.—Explosion incidents¹

Item No.	Facility name and/or location	Elevator	Feed mill	Explosion date	Deaths	Injuries
1	Franklin, TN	X		1/8/58	0	0
2	Huntington, WV		X	1/9/58	0	0
3	Albany, NY		X	3/3/58	2	21
4	Big Lake, MN	X		7/20/58	0	0
5	Bird Island, MN	X		7/28/58	0	0
6	Grand River, OH	X		9/8/58	0	5
7	Colton, CA	X		10/2/58	0	1
8	Lima, OH	X		12/27/58	0	0
9	Kansas City, MO	X		1958	0	0
10	Dalhart, TX	X		1958	0	0
1958 subtotals		8	2		2	27
11	Bellwood, NE	X		3/27/59	0	2
12	Billings, MT	X		4/6/59	0	0
13	Hastings, NE	X		5/15/59	0	0
14	Hayland, NE	X		7/20/59	0	0
15	Baton Rouge, LA	X		11/14/59	0	10
16	Denver, CO	X		12/17/59	0	1
17	Colby, WI		X	12/31/59	2	3
18	Beaver, KS	X		1959	1	2
19	Toledo, OH	X		1959	0	0
20	Union, IL		X	1959	0	0
1959 subtotals		8	2		3	18
21	Jamestown, NY		X	2/2/60	0	0
22	Abernathy, TX	X		2/21/60	0	0
23	Lawton, OK	X		4/27/60	0	2
24	Brownfield, TX	X		7/19/60	4	5
25	Denver, CO		X	8/23/60	0	0
26	Missouri Valley, IA	X		11/6/60	0	0
27	Burkburnett, TX	X		1960	0	1
28	Guntersville, AL	X		1960	0	7
29	Ralston, NE	X		1960	0	1
30	Hart, TX	X		1960	0	2
31	Buffalo, NY		X	1960	0	0
32	Olympia, WA		X	1960	0	0
1960 subtotals		8	4		4	18
33	Lawton, OK	X		3/15/61	0	2
34	Sac City, IA		X	6/5/61	0	0
35	Decatur, IN	X		11/1/61	0	10
36	Racine, MN	X		1961	0	0
37	Union, IA	X		1961	0	2
38	Easton, MD	X		5/4/61	0	0
39	Franklin, KY	X		1961	0	0
40	Fontanelle, NE	X		1961	0	0
41	Perrytown, TX	X		1961	0	3
42	Kansas City, MO		X	1961	0	0
1961 subtotals		8	2		0	17

¹(Refs. 4, 5, 6, 7, 8, and 9) incidents were verified through personal contact with responsible local and state officials and/or facility management.

Explosion incidents

Item no.	Facility name and/or location	Elevator	Feed mill	Explosion date	Number of deaths	Number of injuries
43	St. Louis, MO	X		1/10/62	2	37
44	Mulvane, KS	X		6/8/62	0	5
45	Greenville, OH	X		8/1/62	0	0
46	Bangor, PA	X		8/18/62	0	0
47	Beatrice, NE	X		8/24/62	0	5
48	Happy, TX	X		12/18/62	1	2
49	Corpus Christi, TX	X		1962	0	0
50	St. Louis, MO	X		1962	0	2
51	Stouchsburg, PA		X	1962	0	0
1962 subtotals		8	1		3	51
52	Elkhart, KS	X		1/ /63	1	2
53	Phillips, WI	X		2/19/63	0	7
54	Meade, KS		X	2/26/63	0	3
55	Pekin, IL	X		3/7/63	0	0
56	Ashton, IA		X	5/21/63	0	2
57	Danville, IL	X		8/2/63	1	6
58	Chicago, IL	X		8/10/63	0	0
59	Arapahoe, NE		X	8/14/63	0	5
60	Holdredge, NE		X	8/15/63	0	3
61	Buffalo, NY		X	9/11/63	—	—
62	Garden Plain, KS		X	11/18/63	0	0
63	Bow, NH	X		3/2/63	0	0
64	Salem, NE	X		1963	0	2
65	Sioux City, IA	X		1963	1	0
1963 subtotals		8	6		3	30
66	Jefferson, IA		X	1/31/64	0	0
67	Fort Smith, AR		X	2/21/64	2	7
68	Beeler, KS		X	4/1/64	0	1
69	Hanston, KS	X		4/3/64	0	0
70 ¹	Jonesboro, AR		X	5/28/64	0	3
71	Superior, IA		X	7/7/64	0	0
72	Kingston, IA	X		8/12/64	0	3
73	Chicago, IL		X	1964	1	8
1964 subtotals		2	6		3	22
74	Fort Worth, TX	X		2/26/65	2	4
75	Maryville, MO		X	7/ /65	0	0
76	Saginaw, TX	X		6/16/65	0	0
77	Menomonie, WI		X	10/28/65	0	1
78	Charleston, IL	X		10/31/65	0	0
79	St. Joseph, MO		X	1965	0	0
80	Norwich, KS	X		1965	0	0
81	Belleville, KS	X		1965	0	0
82	Hoopeston, IL	X		1965	0	0
1965 subtotals		6	3		2	5
83	Inwood, IA		X	5/9/66	0	2
84	Hennessey, OK	X		5/13/66	0	1
85	Mankato, MN		X	7/20/66	0	4
86	Corn, OK	X		7/25/66	0	0
87	Barron, WI	X		8/31/66	2	5
88	Burlington, OK	X		10/20/66	0	0
89	Maple Park, IL	X		1966	0	4

¹ Rice mill

Explosion incidents

Item no.	Facility name and/or location	Elevator	Feed mill	Explosion date	Number of deaths	Number of injuries
90	Carrollton, TX	X		1966	0	1
91	Logan, IA	X		1966	0	1
92	Rock Valley, IA	X		1966	0	4
93	Irwin, IA	X		1966	0	0
94	North Kansas City, MO		X	1966	0	0
95	Middleton, WI		X	1966	0	0
96	Honey Grove, TX		X	1966	0	0
1966 subtotals		9	5		2	22
97	Mount Pulaski, IL	X		3/6/67	0	1
98	Buffalo, NY		X	5/21/67	0	0
99	Maroa, IL	X		7/3/67	0	0
100	Holdredge, NE	X		7/25/67	0	1
101	Waco, NE	X		9/20/67	0	0
102	Lee's Summit, MO	X		10/20/67	0	0
103	Carthage, TX		X	11/24/67	0	0
104	McKenzie, TN		X	12/8/67	0	0
105	Trumbull, NE	X		1967	0	3
106	Jeffersonville, OH	X		1967	0	0
107	New Waverly, IN	X		1967	0	0
108	Brush, CO	X		8/27-31/67	0	2
109	Sikeston, MO	X		1967	1	1
110	Tekamah, NE	X		1967	0	0
111	Cincinnati, OH	X		1967	0	0
112	Oxford, KS		X	1967	0	0
113	Nashville, TN		X	1967	0	6
1967 subtotals		12	5		1	14
114	McComb, MS		X	2/15/68	4	7
115	Fruitland, ID		X	4/22/68	0	5
116	Lakefield, MN	X		5/1/68	0	0
117	Montevideo, MN	X		5/27/68	0	0
118	El Reno, OK	X		5/28/68	1	1
119	Corpus Christi, TX	X		7/27/68	0	1
120	Livermore, IA	X		7/30/68	4	2
121	Danville, IL		X	9/20/68	2	10
122	Hydro, OK		X	10/8/68	0	1
123	Imperial, NE	X		10/11/68	0	4
124	Newaygo, MI	X		1968	0	0
125	Lariat, TX	X		1968	0	0
126	Ashland, NE	X		1968	0	0
127	Sandy Lake, PA		X	1968	0	0
128	Mondovi, WI		X	1968	1	3
129	Fort Recovery, OH		X	1968	0	4
1968 subtotals		9	7		12	38
130	Holdredge, NE		X	3/10/69	0	2
131	Yates Center, KS	X		4/13/69	0	0
132	Zilwaukee, MI		X	9/15/69	3	3
133	College Corner, OH		X	10/11/69	0	0
134	*Boone Valley Coop. Eagle Grove, IA		X	12/23/69	1	3
135	Waco, TX		X	1969	0	5
1969 subtotals		1	5	5	4	13

*Incidents marked with an asterisk are included in a comparative study of 66 facilities.

Explosion incidents

Item no.	Facility name and/or location	Elevator	Feed mill	Explosion date	Number of deaths	Number of injuries
136	Grafton, NE	X		4/2/70	0	0
137	Alger, OH	X		4/3/70	0	2
138	Grafton, NE	X		4/12/70	0	1
139	Albion, NE	X		6/30/70	0	2
140	Destrehan, LA	X		9/13/70	0	3
141	Brewster, MN	X		12/5/70	0	0
142	Ericson, IA	X		1970	0	1
143	Trumbull, NE	X		1970	0	0
144	Findlay, OH	X		1970	0	4
145	Chicago, IL	X		1970	1	1
1970 subtotals		10	0		1	14
146	Vicksburg, MS	X		1/19/71	0	2
147	Hardy, IA	X		1/26/71	0	1
148	Buffalo, NY		X	2/3/71	—	—
149	Swea City, IA	X		5/7/71	0	3
150	Hutchins, IA	X		7/22/71	0	1
151	Chicago, IL	X		10/12/71	4	5
152	Chicago, IL	X		1971	0	2
153	Minden, IA	X		1971	0	0
154	Sebewaing, MI	X		1971	0	0
155	Chester, MT	X		1971	0	0
1971 subtotals		9	1		4	14
156	Buffalo, NY		X	1/2/72	6	10
157	Winterset, IA		X	1/18/72	0	1
158	Dighton, KS	X		1/26/72	0	0
159	Buffalo, NY		X	2/23/72	0	0
160	*Mount Airey Feeds & Vitamin Pre-Mixes N. Little Rock, AR		X	6/26/72	0	4
161	Boyden, IA		X	7/6/72	0	0
162	Destrehan, LA	X		10/10/72	0	3
163	*El Rancho Milling Co. Clovis, NM		X	10/23/72	1	5
1972 subtotals		2	6		7	23
164	Lawrence, NE	X		1/25/73	0	1
165	Thomasboro, IL	X		8/13/73	0	0
166	Big Springs, NE	X		8/27/73	0	0
167	*Big Thompson Milling Loveland, CO		X	9/26/73	2	6
168	*Allied Mills, Inc., Cordele, GA		X	10/16/73	0	3
169	Hutchinson, KS	X		10/23/73	0	0
170	Sargent, NE	X		10/27/73	0	0
171	Blue Springs, NE	X		1973	0	0
1973 subtotals		6	2		2	10

Explosion incidents

Item no.	Facility name and/or location	Elevator	Feed mill	Explosion date	Number of deaths	Number of injuries
172	Goehner, NE	X		1/2/74	0	0
173	*Krause Milling Co. St. Joseph, MO		X	2/22/74	1	2
174	Sioux City, IA	X		4/30/74	4	1
175	Memphis, TN	X		5/23/74	0	11
176	Knierim, IA	X		5/28/74	0	0
177	Gurley's Selma, NC		X	6/11/74	1	2
178	Mahomet, IL	X		6/13/74	0	0
179	Allied Mills Portsmouth, VA		X	7/18/74	0	3
180	*Far-Mar-Co (now Farmland Soy Processing) St. Joseph, MO		X	8/16/74	0	0
181	*Conrad Cooperative Conrad, IA	X		8/21/74	0	1
182	Jefferson, IA	X		8/22/74	3	0
183	*Greenly Elevator Independence, IA	X		12/18/74	0	1
184	Weston, NE	X		1974	0	0
185	Yarmouth, IA	X		1974	0	0
186	Laurinburg, NC		X	6/18/74	4	16
1974 subtotals		10	5		13	37
187	Levelland, TX	X		3/3/75	0	0
188	Edinburg, IL	X		4/1/75	0	0
189	Davenport, IA	X		5/23/75	1	2
190	Hutchinson, KS	X		8/5/75	0	2
191	Attica, NY		X	8/15/75	0	0
192	Abilene, Kansas		X	9/12/75	0	0
193	*Far-Mar-Co Lincoln, NE	X		9/25/75	3	2
194	*Ceylon Coop. Ceylon, MN	X		10/19/75	0	0
195	*Clinton Corn Processing Co. Clinton, IA		X	12/20/75	0	13
1975 subtotals		6	3		4	19

Explosion incidents

Item no.	Facility name and/or location	Elevator	Feed mill	Explosion date	Number of deaths	Number of injuries
196	*Adrian Elevator Butterfield, MN	X		1/21/76	0	2
197	**Michigan Farm Bureau Zilwaukee, MI	X		1/22/76	5	13
198	*Wendlands Farm Products Temple, TX		X	2/3/76	1	3
199	*Missouri Farmers Association Sedalia, MO	X		2/7/76	0	1
200	**Goodpasture Houston, TX	X		2/22/76	9	7
201	**Kokomo Grain Kokomo, IN	X		2/25/76	1	2
202	*Farmers Union Coop. and Feed Mill Rice Lake, WI	X		2/27/76	0	4
203	*Bunge Shawneetown, IL	X		3/5/76	0	4
204	*Tiffin Farmers Coop. Tiffin, OH	X		5/8/76	0	1
205	*Holdrege Coop. Holdrege, NE	X		5/21/76	0	2
206	*New Era Milling Arkansas City, KS		X	5/23/76	0	2
207	*Tiffin Farmers Coop. Tiffin, OH	X		6/18/76	0	3
208	*Fairfax Grain and Supply Coop. Fairfax, MN	X		6/12/76	0	0
209	**Krause Milling Milwaukee, WI		X	7/23/76	0	0
210	*Wadsworth Grain Dryer Wadsworth, TX	X		7/25/76	1	3
211	**Cargill, Inc. St. Anne, IL	X		8/3/76	1	3
212	*Central Soya Hastings, NE	X		8/13/76	1	2
213	*Delevan Farmers Delevan, MN	X		8/19/76	2	3
214	**Ohio Grain Mechanicsburg, OH	X		11/6/76	1	3
215	*Continental Grain Elizabeth City, NC	X		11/8/76	0	6
216	*McAlester Milling Co. McAlester, OK		X	12/20/76	0	18
217	Lawton Coop Elevator Lawton, OK	X		12/23/76	0	0
1976 subtotals		18	4		22	82

**Incidents marked with double asterisks are included in a more detailed study of 15 facilities.

Explosion incidents

Item no.	Facility name and/or location	Elevator	Feed mill	Explosion date	Number of deaths	Number of injuries
218	*Hutting Elevator New Richland, MN	X		1/19/77	0	1
219	*Penick & Ford, Ltd. Cedar Rapids, IA		X	2/27/77	1	2
220	*Macoupin Service, Co. Palmyra, IL	X		4/27/77	0	5
221	**Burdick Grain Minneapolis, MN	X		5/11/77	1	0
222	*Mississippi Delta Rice Co. (now Mississippi Rice Growers Assn.) Cleveland, MS		X	5/18/77	1	1
223	**Indiana Grain Logansport, IN	X		5/25/77	0	4
224	*Charles Meyers Grain Seymour, TX	X		7/24/77	0	0
225	*Archer-Daniels-Midland (Tabor Grain) Decatur, IL		X	7/30/77	0	0
226	**Garvey Grain Chicago, IL	X		8/4/77	2	3
227	*ADM Decatur, IL		X	8/31/77	0	3
228	**Producers Grain Corpus Christi, TX	X		9/13/77	0	0
229	*Grant Coop Elevator Grant, NE	X		10/18/77	0	1
230	*Petersburg Coop. Petersburg, TX	X		10/26/77	1	0
231	*Molinas de Puerto Rico, Inc., San Juan, PR		X	11/22/77	0	0
232	*Kimball Milling Durant, OK		X	11/30/77	0	15
233	*Simpson Grain Woodward, OK	X		12/7/77	0	1
234	*Behimer & Kissiner, Inc. Wayne City, IL	X		12/21/77	1	1
235	*Sunshine Mills Tupelo, MS		X	12/22/77	4	15
236	**Continental Westwego, LA	X		12/22/77	36	9
237	*Lexington Mill Lexington, NE		X	12/26/77	0	0
238	**Farmers Export Galveston, TX	X		12/28/77	18	23
1977 subtotals		13	8		65	84

Explosion incidents

Item no.	Facility name and/or location	Elevator	Feed mill	Explosion date	Number of deaths	Number of injuries
239	**Desert Gold Feed Liberty, MO		X	1/19/78	3	6
240	*Crescent Coop Crescent, OK	X		3/9/78	0	0
241	**Tabor Mills N. Kansas City, MO		X	3/16/78	0	3
242	*Farmers Coop Ulysses, NE	X		3/21/78	0	1
243	*Fuzzy's Feed Florence, AL		X	4/5/78	0	0
244	**Tabor Mills N. Kansas City, MO		X	4/21/78	1	35
245	*Niantic Farms Niantic, IL	X		4/28/78	0	0
246	*Persson Grain Trimont, MN	X		5/26/78	0	0
247	*Pillsbury Co. Roberts, IL	X		8/14/78	0	0
248	*Bunge Corp. Savage, MN	X		10/3/78	3	2
249	*Chouteau Elevator (Continental Co.) Kansas City, MO	X		10/31/78	0	0
250	*ADM Decatur, IL		X	12/11/78	0	0
1978 subtotals		7	5		7	47

Table 41.—Summary of explosion incidents, 1958-1978

Location	Number	Deaths	Injuries
Grain elevators	168	120	325
Feed mills	82	44	280
Totals	250	164	605

Table 42.—Incidents per year

Year	Incidents	Year	Incidents
1958	10	1969	6
1959	10	1970	10
1960	12	1971	10
1961	10	1972	8
1962	9	1973	8
1963	14	1974	15
1964	8	1975	9
1965	9	1976	22
1966	14	1977	21
1967	17	1978	12
1968	16		

Figure 15

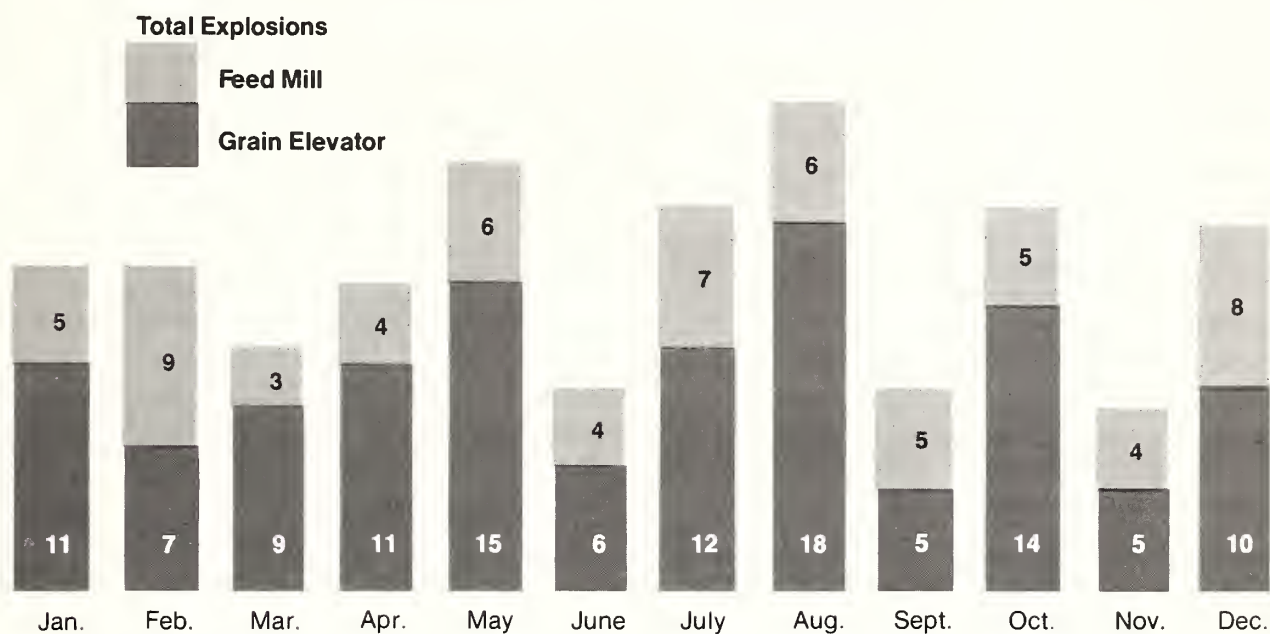
**Grain Elevator and Feedmill Dust Explosions
Incidents by Month in the Last 21 Years****Figure 15 Grain Elevator and Feed Mill Dust Explosions by Month in Last 21 Years**

Table 43.—Explosion incidents by state 1958 to 1978

State Number	State	Number of explosion incidents	Number of incidents in elevators	Number of incidents in feed mills	Number of deaths	Number of injuries
1	Alabama	2	1	1	0	7
2	Alaska	0				
3	Arizona	0				
4	Arkansas	3	0	3	2	14
5	California	1	1	0	0	1
6	Colorado	4	2	2	2	9
7	Connecticut	0				
8	Delaware	0				
9	Florida	0				
10	Georgia	1	0	1	0	3
11	Hawaii	0				
12	Idaho	1	0	1	0	5
13	Illinois	27	21	6	13	56
14	Indiana	4	4	0	1	16
15	Iowa	30	20	10	15	46
16	Kansas	16	10	6	2	17
17	Kentucky	1	1	0	0	0
18	Louisiana	4	4	0	36	25
19	Maine	0				
20	Maryland	1	1	0	0	0
21	Massachusetts	0				
22	Michigan	4	3	1	8	16
23	Minnesota	15	14	1	6	12
24	Mississippi	4	1	3	9	25
25	Missouri	16	7	9	8	87
26	Montana	2	2	0	0	0
27	Nebraska	32	28	4	4	40
28	Nevada	0				
29	New Hampshire	1	1	0	0	0
30	New Jersey	0	0			
31	New Mexico	1	0	1	1	5
32	New York	9	0	9	8	31
33	North Carolina	3	1	2	5	24
34	North Dakota	0				
35	Ohio	13	11	2	1	22
36	Oklahoma	12	9	3	1	41
37	Oregon	0				
38	Pennsylvania	3	1	2	0	0
39	Rhode Island	0				
40	South Carolina	0				
41	South Dakota	0				
42	Tennessee	4	2	2	0	17
43	Texas	24	20	4	37	60
44	Utah	0				
45	Vermont	0				
46	Virginia	1	0	1	0	3
47	Washington	1	0	1	0	0
48	West Virginia	1	0	1	0	0
49	Wisconsin	8	3	5	5	23
50	Wyoming	0				
51	Puerto Rico	1	0	1	0	0
Totals:						
32 States and						
Puerto Rico		250	168	82	164	605

Appendix B

EXPLOSION QUESTIONNAIRE

- A. Name:
- B. Address:
- C. Explosion/fire:
 - 1. Time:
 - 2. Date:
 - 3. Kind of grain being handled at time of explosion:
 - 4. Major kind of grain processed by facility:
 - 5. Cause of explosion, if known:
 - 6. Number of injuries:
 - 7. Number of deaths:
 - 8. Operating at the time of explosion:
 - 9. Volume of grain handled in past: (3-4 years prior to incident):
 - a. Increased:
 - b. Decreased:
 - c. Variable:
 - 10. Location of explosion:
 - 11. Contact:

Table 44.—Grain dust explosions — data from sample of 15

Questions	Elevator count	Percentage	Questions	Elevator count	Percentage
A. BACKGROUND			2. Months during which explosions occurred		
1. Time built			a. January	2	13
a. Prior to 1931	1	7	b. February	2	13
b. 1931-1945	3	20	c. March	1	7
c. 1946-1962	8	53	d. April	1	7
d. 1963-1978	3	20	e. May	2	13
Totals	15	100%	f. June	0	0
2. Major additions			g. July	1	7
a. Prior to 1931	0	0	h. August	2	13
b. 1931-1945	0	0	i. September	1	7
c. 1946-1962	1	17	j. October	0	0
d. 1963-1978	5	83	k. November	1	7
Totals	6	100%	l. December	2	13
3. Construction			Totals	15	100%
a. Concrete	0	0	3. Kind of grain handled at time of explosion		
b. Concrete/steel	14	93	a. Corn	11	73.2
c. Wood	1	7	b. Wheat	1	6.7
d. Steel	0	0	c. Pellets	1	6.7
e. Concrete/steel/wood	0	0	d. Aureomycin—soybean meal	1	6.7
Totals	15	100%	e. Milo	1	6.7
4. Construction-major additions			Totals	15	100%
a. Concrete	0	0	4. Operating at time of explosion		
b. Concrete/steel	5	100	a. Yes	14	93
c. Wood	0	0	b. No	1	7
d. Steel	0	0	Totals	15	100%
e. Concrete/steel/wood	0	0	5. Probable section of elevator in which explosion originated		
Totals	5	100%	a. Headhouse	6	40
5. Condition of equipment at time of explosion			b. Elevator leg—rail dump	2	13
a. Old—original equipment	2	13	c. Dust systems	2	13
b. New	1	7	d. Warehouse	1	7
c. Rebuilt	12	80	e. Tunnels	1	7
Totals	15	100%	f. Not known	3	20
6. Storage capacity			Totals	15	100%
a. Less than 2 million	4	27	6. Extent of damage to facility		
b. 2 to 6 million	9	60	a. Minor	3	20
c. 6 to 10 million	2	13	b. Moderate	1	7
Totals	15	100%	c. Major	5	33
B. EXPLOSION DATA			d. Total	6	40
1. Date and time of explosion			Totals	15	100%
a. First shift	6	40	7. Probable source of ignition		
b. Second shift	7	46	a. Welding	3	20.0
c. Third shift	1	7	b. Hot bearings	1	6.67
d. Non-working hours	1	7	c. Lightning	1	6.67
Totals	15	100%	d. Static electricity	1	6.67
			e. Arcing of electrical wires	1	6.67
			f. Tramp metal	1	6.67
			g. Rock in leg	1	6.66
			h. Extraction of oil from corncake	1	6.66
			i. Switch engine on rail dump	1	6.66
			j. Unknown	4	26.67
			Totals	15	100%

Data On Explosions

Questions	Elevator count	Percentage
8. Weather conditions near time of explosions		
a. Humidity		
1. 0-25%	1	7
2. 26-35%	2	13
3. 36-45%	1	7
4. 46-55%	1	7
5. 56-75%	5	33
6. 76-95%	5	33
Totals	15	100%
b. Temperature		
1. 0 to 32 degrees	4	27
2. 33 to 53 degrees	2	13
3. 54 to 73 degrees	7	46
4. 74 to 95 degrees	1	7
5. 96 to 100 degrees	1	7
Totals	15	100%
C. RESPONSE TO EXPLOSION		
1. Fire departments		
a. Volunteer	6	40
b. Paid	8	53
c. Paid mutual aid society	1	7
Totals	15	100%
2. FBI investigations		
a. Yes	1	7
b. No	14	93
Totals	15	100%
3. AT&F investigations		
a. Yes	5	33
b. No	10	67
Totals	15	100%
4. OSHA investigations		
a. Yes	12	80
b. No	3	20
Totals	15	100%
5. State fire marshal investigations		
a. Yes	7	47
b. No	8	53
Totals	15	100%
6. State police investigations		
a. Yes	2	13
b. No	13	87
Totals	15	100%
7. Sheriff and local police investigations		
a. Yes	5	33
b. No	10	67
Totals	15	100%
8. Local fire departments' investigations		
a. Yes	6	40
b. No	9	60
Totals	15	100%

Data On Explosions

Questions	Elevator count	Percentage
D. INSPECTIONS PRIOR TO EXPLOSIONS		
1. OSHA		
a. Yes	8	53.4
b. No	7	46.6
Totals	15	100%
2. EPA		
a. Yes	9	60
b. No	6	40
Totals	15	100%
3. FDA		
a. Yes	4	27
b. No	11	73
Totals	15	100%
4. State fire marshal		
a. Yes	0	0
b. No	15	100
Totals	15	100%
5. Local fire department		
a. Yes	9	60
b. No	6	40
Totals	15	100%
6. Insurance companies		
a. Yes	15	100
b. No	0	0
Totals	15	100%
E. MAINTENANCE		
1. Records		
a. Written instructions	1	7
b. Nothing in writing	12	80
c. Data not available (under litigation)	2	13
Totals	15	100%
2. Personnel		
a. Especially hired for maintenance	12	80
b. Part-time specialist	1	7
c. Data not available (under litigation)	2	13
Totals	15	100%
3. Preventive maintenance		
a. Yes	2	13
b. No	11	74
c. Data not available (under litigation)	2	13
Totals	15	100%
F. HOUSEKEEPING		
1. Records		
a. Written instructions	3	20
b. Nothing in writing	10	67
c. Data not available (under litigation)	2	13
Totals	15	100%

Data On Explosions

Questions	Elevator count	Percentage
2. Personnel		
a. Full-time housekeeper	6	40
b. None	2	13
c. Each person responsible for housekeeping in own area	4	27
d. Part-time	1	7
e. Data not available (under litigation)	2	13
Totals	15	100%
G. DUST SYSTEMS		
1. Yes	10	67
2. No	3	20
3. Data not available (under litigation)	2	13
Totals	15	100%
4. Disposition of dust collected		
a. Placed into grain stream	9	60
b. Not returned to grain stream	3	20
c. Part returned and part removed	1	7
d. Data not available (under litigation)	2	13
Totals	15	100%
H. SAFETY		
1. Records		
a. Written	2	13
b. Unwritten	11	74
c. Data not available (under litigation)	2	13
Totals	15	100%
2. Emergency evacuation plans		
a. Yes	1	7
b. No	12	80
c. Data not available (under litigation)	2	13
Totals	15	100%
3. Safety meetings		
a. Yes	7	46.7
b. No	6	40
c. Data not available (under litigation)	2	13.3
Totals	15	100%

Data On Explosions

Questions	Elevator count	Percentage
4. Training on safety		
a. Yes	14	93
b. No	1	7
Totals	15	100%
I. SECURITY		
1. Guards		
a. Yes	1	7
b. No	14	93
Totals	15	100%
2. Fences		
a. Yes	3	20
b. No	12	80
Totals	15	100%
3. Passes		
a. Yes	1	7
b. No	14	93
Totals	15	100%
4. Television monitors		
a. Yes	0	0
b. No	15	100
Totals	15	100%
5. Alarms		
a. Yes	0	0
b. No	15	100
Totals	15	100%

Table 45.—Grain dust explosions — data from sample of 66

Questions	Number of elevators	Percent of elevators
1. Time of explosion		
a. First shift	49	74.2
b. Second shift	14	21.2
c. Third shift	2	3.0
d. Non-working shift	1	1.6
Totals	66	100.0%
2. Months in which explosions occurred		
a. January	4	6.0
b. February	7	10.6
c. March	4	6.0
d. April	4	6.0
e. May	7	10.6
f. June	4	6.0
g. July	5	7.6
h. August	8	12.1
i. September	3	4.6
j. October	8	12.3
k. November	3	4.6
l. December	9	13.6
Totals	66	100.0%
3. Kind of grain being handled at time of explosion		
a. Corn	27	40.9
b. None	11	16.7
c. Pellets & feed—processing	7	10.6
d. Milo	7	10.6
e. Soybeans	4	6.1
f. Wheat	4	6.1
g. Soybean processing	3	4.5
h. Wet milling corn	1	1.5
i. Aureomycin-soybean meal	1	1.5
j. Rice hulls	1	1.5
Totals	66	100.0%

Questions	Number of elevators	Percent of elevators
4. In operation at the time of explosion.		
a. Yes	55	83.3
b. No	11	16.7
Totals	66	100.0%
5. Probable source of ignition		
a. Unknown	17	25.7
b. Welding/cutting	16	24.3
c. Hot bearing	7	10.6
d. Tramp metal	6	9.1
e. Electrical	4	6.0
f. Vapor explosion	2	3.1
g. Heating system	2	3.1
h. Dust system	2	3.1
i. Lightning	1	1.5
j. Static electricity	1	1.5
k. Rock in leg	1	1.5
l. Extraction of oil from corncake	1	1.5
m. Switch engine on rail dump	1	1.5
n. Choked leg	1	1.5
o. Electric cord in leg	1	1.5
p. Volatile solvent escaped from the processing of soybeans	1	1.5
q. Grain hung up in drier	1	1.5
r. Fan blade caused spark	1	1.5
Totals	66	100.0%
6. Volume of grain handled in the past		
a. Increased	25	37.9
b. Decreased	9	13.6
c. Variable	10	15.2
d. Same	22	33.3
Totals	66	100.0%

Appendix D

EXPORT ELEVATOR SURVEY QUESTIONNAIRES

Appendix D consists of three questionnaires used by the Task Force in its survey of export elevator operations.

Task Force Survey

I BACKGROUND

A. Facility name _____

1. Type: _____

2. Business address: _____

3. Mail address: _____

4. Phone: _____

(name) _____

B. Owner/operator (address): _____

C. Management structure: _____

Title	Name	Duties	Length present position
1. _____	_____	_____	_____
Bio. _____	_____	_____	_____
2. _____	_____	_____	_____
Bio. _____	_____	_____	_____
3. _____	_____	_____	_____
Bio. _____	_____	_____	_____
4. _____	_____	_____	_____
Bio. _____	_____	_____	_____
5. _____	_____	_____	_____
Bio. _____	_____	_____	_____

D. Physical plant:

1. Built: _____ Type construction _____

2. Plant configuration (obtain diagram) _____

3. Original design thruput: _____

4. Storage _____

5. Construction additions:

a. When?	b. What?
----------	----------

6. Present storage capacity:

a. Type:	b. No.	c. Amount
----------	--------	-----------

In house		
----------	--	--

Tank		
------	--	--

Silo		
------	--	--

Flat		
------	--	--

Other		
-------	--	--

Present handling — total capacity: _____

1. Unloading:

a. Type	b. Facility descrip./no.	c. Amt. handled/hr.
Box	_____	_____
Hopper	_____	_____
Truck	_____	_____
Barge	_____	_____
Other	_____	_____

2. Loading:

a. Type	b. Facility descrip./no.	c. Amt. handled/hr.
Rail	_____	_____
Truck	_____	_____
Water	_____	_____

(Describe fully)

3. Total thruput (yearly for 5 yrs.):

	Accounting period	Amount
a.	_____	_____
b.	_____	_____
c.	_____	_____
d.	_____	_____
e.	_____	_____

4. Maximum monthly thruput: _____ 5. Normal _____

6. Any trends _____

7. Products handled:

a. Grain (list types)	b. Amounts or percentages
_____	_____
_____	_____
_____	_____
_____	_____

c. Other (screenings, flour, meal, etc.) List:

8. Any trends _____

9. Equipment (obtain diagram with location of following):

a. Receiving legs/belts — Total: _____

1. Location (list)	2. Capacity/hr.	3. Constructed of
_____	_____	_____
_____	_____	_____
_____	_____	_____

b. Shipping legs/belts: _____

1. Location (list)	2. Capacity/hr.	3. Constructed of
_____	_____	_____
_____	_____	_____
_____	_____	_____

c. In house legs/belts: _____

1. Location (list)	2. Capacity/hr.	3. Constructed of
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

d. Dust systems (diagrams & engineering specs.)

1. Type	2. Manufacturer	3. Location	4. Specs.
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

5. When installed/additions: _____

6. How maintained/instructions-schedules: _____

7. What is done with dust collected: _____

e. Driers:

1. Type/mfr.	2. When built	3. Location	4. Capacity per hr.	5. Normal temp.
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

6. Remarks: _____

f. Cleaners/scalpers:

1. Type/mfr.	2. When built	3. Location	4. Capacity per hr.
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

5. Remarks: _____

g. Scales:

1. Type/mfr.	2. When installed	3. Location	4. Capacity per hr.
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

5. Location of weight control room: _____

6. Remarks _____

h. Other (trippers, turnheads, switch engines, etc.): List & describe

1. _____

2. Does the facility use mostly electric, air, hydraulic, or manual equipment? _____

i. Spouting (types & describe): _____

10. Employees:

a. Total no. employed: _____

b. Shift No. 1 _____ No. 2 _____ No. 3 _____

c. Contractors (total & by shift): _____

Shift No. 1 _____ No. 2 _____ No. 3 _____

d. Union (contract available) specify: _____

e. Employee turnover/seasonal employment: describe _____

II SAFETY/FIRST AID:

A. Written instructions/program available: _____

1. Employee training:

a. Orientation: _____

b. Additional: _____

2. Meetings – what involved? how often? _____

a. FGIS attendance? _____

3. Is there an emergency plan in case of fire or explosion? _____

4. Emergency drills? _____

5. Emergency contact no's? _____

a. What agencies? _____

B. Safety equipment – prevention:

1. Are any of the following used:

a. Ammeters (electric motors)? _____

b. Hot bearing indicators? _____

c. Blast dampers: where? _____

d. Overload indicators (belts, legs)? _____

e. Automatic cutoff devices: where? _____

f. Devices registering temperature in bins? describe: _____

- g. "Lockout" systems/stop cords: _____
- h. Bindicators: _____
- C. Safety equipment – reaction:
 - 1. Does the facility have any of the following:
 - a. Sprinkler/standpipe? describe specs: _____

 - b. Fire extinguishers? type? no.? locations? _____

 - c. Alarm systems? type? how activated? _____

 - d. Other? _____

 - 2. Is equipment in a, b, c, or d inspected? _____
 - 3. How is equipment in a, b, c, or d serviced? _____
 - 4. What type of H₂O supply is available? _____

III MAINTENANCE:

- A. Number/shift and type – season: _____
- B. Written instructions, copy – logs: _____
- C. Who does what: _____
- D. Pneumatic or electric tools, non ferrous: _____
- E. Hot work – precautions: how done? _____
- F. How performed? continuous: _____ shift only % _____
priorities: _____
- G. Other: dust system maintenance: _____

IV HOUSEKEEPING:

- A. Number/shift – season: _____
- B. Written instructions: _____
- C. Change in capacity more employees: _____
- D. Equipment – air/vacuum: _____
- E. Implementation of instructions: _____
- F. Other: _____

V SECURITY:

- A. Access control systems: _____
 - 1. Passes: _____
 - 2. Guards: _____
 - 3. Fences (where): _____
 - 4. Special equipment: _____
 - a. Alarms: _____
 - b. TV: _____
 - 5. Implementation/problems: _____
- B. Contractors – how handled: _____
 - 1. Prior notification: _____
 - 2. Supervision during work: _____
 - 3. Check when job done: _____

VI LOCAL AUTHORITIES:

A.	Inspections by: When?	Frequency?	Reports?	Citations?
1.	OSHA: _____			
2.	EPA: _____			
3.	FDA: _____			
4.	FGIS: _____			
5.	Fire department: _____			
6.	Building inspector: _____			
7.	Other (electric & plumbing): _____			
B.	Fire accident history: _____			
C.	Emergency response: _____			
1.	Who: _____			
2.	When/particulars: _____			
3.	Others: _____			
	a. Civil defense: _____			
	b. State: _____			
	c. Local: _____			
	d. Coordination capability: _____			

FGIS Interviews

(at least two, if possible three)

Field office supervisor

Weights shift leader

Weights rover

Inspection shift leader

I PURPOSE:

- A. To determine degree of implementation of 370-3 and hazard alert.
- B. Identify problem areas.
- C. Substantiate information from other sources.

II BACKGROUND:

- A. Name _____
- B. Title _____
- C. Length of employment – elevator _____ FGIS _____
- D. Describe duties – training by FGIS _____

III KNOWLEDGE OF 370-3 AND HAZARD ALERT

- A. Awareness of system _____
- B. Understanding of system _____
- C. Implementation (ever used, if so, results) _____
- D. Problems/suggestions _____

IV PROBLEM AREAS IN ELEVATOR

Operation

A. FGIS – elevator relations _____

B. Housekeeping _____

C. Maintenance _____

Task Force Survey of Elevators

FGIS employees

A. Inspection shift leaders

B. Weighing shift leaders

1. Name?
2. Length of employment with FGIS?
3. Length of time employed at elevator?
4. Length of time in present position?
5. Present position?
6. Normal working hours?
7. What percent of working time is spent in the elevator?
8. Where are the lab and control room located?
9. Have you ever received any safety instruction or first aid training?
10. Are you aware of any procedures to be used in case of emergencies?
11. Are there any drills in such emergency procedures?
12. Are these drills elevator drills or FGIS drills?
13. Do you know where fire exists are located?
14. Are you aware of where fire extinguishers, fire hoses or water buckets are located?
15. Do you know where fire alarms are located?
16. Do you have a first aid kit? Is it complete?
17. Are you provided with respirators or dust masks?
18. Do you have life jackets, hard hats or protective shoes?
19. Are there radios for everyone's use (walki-talkies)?
20. Does the inspection laboratory or weigh station have an elevator diagram or flow chart marked with the duty station of every FGIS employee in the elevator?
21. How often does the rover make his rounds in the elevator?
22. What does this include?
23. Does the rover ever check outside of the elevator? For instance, marine legs, truck or rail dumps, inspection labs, or other places such as driers or processing areas?
24. Is the elevator equipped with a man lift, stairs, or with an elevator?
25. Does the rover check to see that fire doors are maintained in working order?
26. What is your opinion of the elevator's equipment maintenance program? Is it good, bad or indifferent?

27. What is your opinion of the elevator's housekeeping program?
28. If you happen to notice hazard conditions, do you report them?
29. When hazardous conditions or malfunctioning machinery are noticed, how long does it usually take to repair them? Who does these repairs?
30. In your estimation, are these repairs a good job or only a patch up?
31. Does the elevator have an active preventive maintenance program and does the elevator ever have any repair shutdowns?
32. Do you feel that you can identify hazardous conditions or situations?
33. To your knowledge have there ever been any cases of FGIS withholding service because of safety conditions?
34. Have you noticed any hazardous conditions within the past 6 months?
35. Have these conditions been reported? If so, to whom, what action has been taken?
36. Are the safety precautions in the elevator adequate?
37. Do you have any suggestions on how to improve safety?
38. What are the general elevator relations with FGIS?
39. Are you informed of all fires or bomb threats?
40. How often do the dust systems actually operate?

Elevator management

A. Background:

1. Name of the manager or person interviewed?
2. The elevator name and address?
3. How long has the person interviewed served in his present position?

B. Equipment and physical plant:

1. When was the elevator built?
2. What type of grain does the elevator usually move?
3. How many employees work at the elevator?
4. How many elevator legs does the elevator have?
5. What is the maximum loading rate per hour?
6. What volume of grain was the elevator originally planned to handled?
7. What is the total storage capacity?

8. Does the elevator have a maintenance schedule or instructions, including the maintenance of fire extinguishers? Is a copy available?
 9. How many persons work on the maintenance staff?
 10. Is maintenance or repair work performed only during the day shift or during all the shifts?
 11. Does the elevator have a functioning sprinkler system?
 12. Does it have a dust collection system? What type? Manufacturer capacity in CFM?
 13. Does the elevator have leg overload indicators?
 14. Does the elevator have belt overload or hot bearing indicators?
 15. Is the elevator equipped with blast dampers?
 16. Does the elevator have other safety equipment? If so, specify.
- C. Other:
1. How many employees have received safety or first aid training?
 2. Does the elevator have an emergency instruction plan or safety plans? Are copies available?
 3. Does the elevator have frequent emergency drills?
 4. What is the elevator's accident or fire record? Are all fires reported to FGIS?
 5. What is the name of the elevator's insurance company?

Table 46.—Export elevator survey-data summary

Response Areas	FGIS Regions														
	Atlanta			Dallas			Chicago			Seattle			Totals		
	Sample size	Elevator count	Percentage	Sample size	Elevator count	Percentage	Sample size	Elevator count	Percentage	Sample size	Elevator count	Percentage	Sample size	Elevator count	Percentage
General															
1. Time built															
a. Prior to 1931	11	2	18	9	3	33	20	10	50	15	4	27	55	19	35
b. 1931-1945	11	0	0	9	0	0	20	2	10	15	2	13	55	4	7
c. 1946-1962	11	4	36	9	2	22	20	6	30	15	5	33	55	17	31
d. 1963-1978	11	5	45	9	4	44	20	2	10	15	4	27	55	15	27
2. Alterations completed															
a. Prior to 1931	11	0	0	9	0	0	20	2	10	15	0	0	55	2	4
b. 1931-1945	11	0	0	9	1	11	20	1	5	15	1	7	55	3	5
c. 1946-1962	11	1	9	9	3	33	20	5	25	15	6	40	55	15	27
d. 1963-1978	11	4	36	9	5	56	20	1	5	15	7	47	55	17	31
3. Construction materials															
a. Concrete	11	4	36	9	5	56	20	10	50	15	8	53	55	27	49
b. Concrete/steel	11	6	55	9	3	33	20	7	35	15	7	47	55	23	42
c. Wood	11	0	0	9	0	0	20	0	0	15	0	0	55	0	0
d. Steel	11	0	0	9	0	0	20	1	5	15	0	0	55	1	2
e. Concrete/steel/wood	11	1	9	9	1	11	20	2	10	15	0	0	55	4	7
4. Total storage capacity															
a. Less than 2 million	11	1	9	9	0	0	20	2	10	15	4	27	55	7	13
b. 2-6 million	11	7	64	9	6	67	20	12	60	15	9	60	55	34	62
c. 6-10 million	11	3	27	9	3	33	20	4	20	15	2	13	55	12	22
d. More than 10 million	11	0	0	9	0	0	20	2	10	15	0	0	55	2	3
5. Trends in storage capacity															
a. Total increasing	11	7	64	9	6	67	20	13	65	15	11	73	55	37	67
b. Total decreasing	11	0	0	9	0	0	20	0	0	15	1	7	55	1	2
c. No change	11	4	36	9	3	33	20	7	35	15	3	20	55	17	31
6. Unloading facilities															
a. Box	11	7	64	9	8	89	20	11	55	15	12	80	55	38	69
b. Hopper	11	11	100	9	9	100	20	20	100	15	15	100	55	55	100
c. Truck	11	5	46	9	9	100	20	17	85	15	11	73	55	42	76
d. Barge	11	10	91	9	3	33	20	3	15	15	6	40	55	22	40
7. Unloading rates (1,000 bushels/hour)															
a. 15 or less	11	1	9	9	1	11	20	1	5	15	4	27	55	7	13
b. 16-45	11	4	36	9	4	44	20	13	65	15	5	33	55	26	47
c. 46-100	11	5	46	9	4	44	20	5	25	15	6	40	55	20	36
d. Greater than 100	11	1	9	9	0	0	20	1	5	15	0	0	55	2	4
8. Load out facilities															
a. Rail	11	3	27	9	8	89	20	19	95	15	13	87	55	43	78
b. Truck	11	4	36	9	4	44	20	9	45	15	8	53	55	25	46
c. Vessel	11	11	100	9	9	100	20	20	100	15	15	100	55	55	100
9. Maximum load out capacity															
a. 40 or less	11	1	9	9	0	0	20	5	25	15	6	40	55	12	22
b. 41-60	11	3	28	9	5	56	20	12	60	15	5	34	55	25	45
c. 61-80	11	5	45	9	2	22	20	1	5	15	2	13	55	10	18
d. More than 80	11	2	18	9	2	22	20	2	10	15	2	13	55	8	15
10. Have dryers	11	9	82	9	1	11	20	10	50	15	2	13	55	22	40
11. Cleaners/scalpers	11	10	91	9	4	44	20	20	100	15	12	80	55	46	84
12. Location of weight room															
a. In headhouse	11	7	64	9	6	67	20	16	80	15	6	40	55	35	64
b. Away from headhouse	11	3	27	9	2	22	20	2	10	15	1	7	55	8	14
c. Adjacent to the headhouse	11	1	9	9	1	11	20	2	10	15	8	53	55	12	22

Table 46.—Export elevator survey-data summary — Continued

Response Areas	FGIS Regions														
	Atlanta			Dallas			Chicago			Seattle			Totals		
	Sample size	Elevator count	Percentage	Sample size	Elevator count	Percentage	Sample size	Elevator count	Percentage	Sample size	Elevator count	Percentage	Sample size	Elevator count	Percentage
Throughput and products															
13. Throughput changes															
a. Increase	9	3	33	9	0	0	19	7	37	15	1	7	52	11	21
b. Decrease	9	1	11	9	1	11	19	2	11	15	0	0	52	4	8
c. Fluctuates	9	4	45	9	6	67	19	6	32	15	12	80	52	28	54
d. Stable	9	1	11	9	2	22	19	4	21	15	2	13	52	9	17
14. Grain most handled															
a. Wheat	11	0	0	9	6	67	20	9	45	15	13	87	55	28	51
b. Corn	11	9	82	9	2	22	20	8	40	15	2	13	55	21	38
c. Barley	11	0	0	9	0	0	20	1	5	15	0	0	55	1	2
d. Oats	11	0	0	9	0	0	20	0	0	15	0	0	55	0	0
e. Soybeans	11	2	18	9	0	0	20	2	10	15	0	0	55	4	7
f. Sorghum	11	0	0	9	1	11	20	0	0	15	0	0	55	1	2
g. Triticale	11	0	0	9	0	0	20	0	0	15	0	0	55	0	0
h. Flaxseed	11	0	0	9	0	0	20	0	0	15	0	0	55	0	0
i. Rye	11	0	0	9	0	0	20	0	0	15	0	0	55	0	0
15. Other products															
a. Screenings	11	9	82	9	3	33	20	15	75	15	2	13	55	29	53
b. Flour	11	0	0	9	0	0	20	0	0	15	0	0	55	0	0
c. Meal	11	4	36	9	1	11	20	3	15	15	4	27	55	12	22
d. Pellets	11	2	18	9	0	0	20	2	10	15	6	40	55	10	18
e. Chemicals	11	0	0	9	0	0	20	0	0	15	1	7	55	1	2
Staffing															
16. Shifts															
a. 24 hrs./day-seasonal	11	0	0	9	0	0	20	2	10	15	0	0	55	2	4
b. 24 hrs./day-all year	11	10	91	9	1	11	20	1	5	15	0	0	55	12	22
c. 16 hrs./day-seasonal	11	0	0	9	0	0	20	7	35	15	0	0	55	7	13
d. 16 hrs./day-all year	11	0	0	9	8	89	20	1	5	15	7	47	55	16	29
e. 8 hrs./day-seasonal	11	0	0	9	0	0	20	8	40	15	0	0	55	8	14
f. 8 hrs./day-all year	11	1	9	9	0	0	20	1	5	15	8	53	55	10	18
17. Staff															
a. Union	11	6	55	9	5	56	20	18	90	15	0	0	55	29	53
b. Non-union	11	3	27	9	1	11	20	2	10	15	0	0	55	6	11
c. Combined (a & c)	11	2	18	9	3	33	20	0	0	15	0	0	55	5	9
d. Union pool	11	0	0	9	0	0	20	0	0	15	15	100	55	15	27
Safety															
18. Have written instructions	11	11	100	9	5	56	20	16	80	15	7	47	55	39	71
a. Instructions covering protective equipment (i.e. dust masks, etc.)	11	7	64	9	2	22	20	9	45	15	4	27	55	22	40
b. Instructions including proper machinery utilization	11	7	64	9	2	22	20	7	35	15	4	27	55	20	36
c. Instructions including prohibitions on hot work, smoking, etc.	11	7	64	9	2	22	20	10	50	15	4	27	55	30	55
19. Have safety training programs	11	10	91	9	2	22	20	8	40	15	3	20	55	23	42
20. Have safety meetings	11	11	100	9	6	67	20	16	80	15	13	87	55	46	84
21. Have emergency plans containing:															
a. Written instructions	11	9	82	9	3	33	20	10	50	15	8	53	55	30	55
b. Contact numbers	11	9	82	9	5	56	20	11	55	15	5	33	55	30	55
c. Shutdown/security	11	6	55	9	2	22	20	6	30	15	4	27	55	25	45
d. Define employee responsibilities	11	4	36	9	3	33	20	6	30	15	4	27	55	17	31
e. Drills	11	4	36	9	1	11	20	5	25	15	2	13	55	12	22
f. Meeting place	11	8	73	9	2	22	20	7	35	15	6	40	55	23	42
g. Head count	11	4	36	9	2	22	20	5	25	15	1	7	55	12	22

Table 46.—Export elevator survey-data summary — Continued

Response Areas	FGIS Regions														
	Atlanta			Dallas			Chicago			Seattle			Totals		
	Sample size	Elevator count	Percentage	Sample size	Elevator count	Percentage	Sample size	Elevator count	Percentage	Sample size	Elevator count	Percentage	Sample size	Elevator count	Percentage
22. Have safety equipment including															
a. Ammeters	11	8	73	9	7	78	20	16	80	15	14	93	55	45	82
b. Hot bearing indicators	11	1	9	9	0	0	20	0	0	15	0	0	55	1	2
c. Blast dampers	11	3	27	9	5	56	20	5	25	15	5	33	55	18	33
d. Overload indicators	11	10	91	9	5	56	20	15	75	15	14	93	55	44	80
e. Automatic shutoff	11	9	82	9	4	44	20	14	70	15	13	87	55	40	73
23. Standpipes	11	8	73	9	3	33	20	13	65	15	8	53	55	32	58
24. Extinguishers	11	11	100	9	9	100	20	20	100	15	15	100	55	55	100
25. Alarm systems in elevator	11	5	45	9	1	11	20	9	45	15	6	40	55	21	38
Maintenance															
26. Staffing															
a. 24 hours	11	10	91	9	1	11	20	0	0	15	0	0	55	11	20
b. 16 hours/day only	11	0	0	9	2	22	20	11	55	15	4	27	55	17	31
c. 8 hours/day only	11	1	9	9	6	67	20	9	45	15	11	73	55	27	49
27. Average number of maintenance employees/shift															
a. Less than 3	11	0	0	9	2	22	18	4	22	13	5	38	51	11	22
b. 3 to 6	11	5	45	9	1	11	18	10	56	13	8	62	51	24	47
c. 7 to 9	11	3	27	9	4	44	18	3	17	13	0	0	51	10	19
d. More than 9	11	3	27	9	2	22	18	1	6	13	0	0	51	6	12
28. Have written instructions	11	9	82	9	0	0	20	8	40	15	2	13	55	19	35
29. Have checklist	11	5	45	9	2	22	20	4	20	15	4	27	55	15	27
30. Have logs	11	6	55	9	2	22	20	5	25	15	11	73	55	24	44
31. Have hot work precautions—number with written permit required	11	6	55	9	1	11	20	5	25	15	10	67	55	22	40
Housekeeping															
32. Shifts worked															
a. 8 hours/day	11	0	0	9	2	22	19	10	53	15	6	40	54	18	33
b. 16 hours/day	11	0	0	9	2	22	19	2	11	15	2	13	54	6	11
c. 24 hours/day	11	9	82	9	0	0	19	1	5	15	0	0	54	10	19
d. None	11	2	18	9	5	56	19	6	32	15	7	47	54	20	37
33. Average number of employees/shift															
a. Less than 3	11	2	18	9	2	22	19	4	21	15	6	40	54	14	26
b. 3 to 6	11	1	9	9	1	11	19	8	42	15	2	13	54	12	22
c. 7 to 9	11	1	9	9	1	11	19	1	5	15	0	0	54	3	6
d. More than 9	11	5	45	9	0	0	19	0	0	15	0	0	54	5	9
e. None	11	2	18	9	5	56	19	6	32	15	7	47	54	20	37
34. Have written instructions	11	4	36	9	0	0	20	5	25	15	2	13	55	11	20
35. Have preventive checklist	11	4	36	9	0	0	20	3	15	15	1	7	55	8	15
36. Have logs	11	1	9	9	1	11	20	2	10	15	2	13	55	6	11
37. Individual assignments (work cleanup area)	11	0	0	9	1	11	20	8	40	15	1	7	55	10	18
Security															
38. Have passes	11	4	36	9	2	22	20	3	15	15	3	20	54	12	22
39. Have guards															
a. 24 hours/day	11	8	73	9	3	33	20	0	0	15	7	47	54	18	33
b. Nights only	11	3	27	9	3	33	20	7	35	15	5	33	54	18	33
c. Days only	11	0	0	9	0	0	20	0	0	15	0	0	54	0	0
40. Have alarms	11	0	0	9	0	0	20	7	35	15	2	13	54	9	17
41. Have fencing															
a. Completely enclosed	10	4	40	9	3	33	20	2	10	15	7	47	54	16	30
b. Partial	10	5	50	9	1	11	20	5	25	15	3	20	54	14	26
c. None	10	1	10	9	5	56	20	13	65	15	5	33	54	24	44
42. Contractors															
a. Total supervision	11	8	73	9	3	33	19	11	58	15	9	60	54	31	57
b. Partial supervision	11	3	27	9	1	11	19	7	37	15	6	40	54	17	32
c. Final check only	11	0	0	9	5	56	19	1	5	15	0	0	54	6	11

DUST SURVEY QUESTIONNAIRES

Appendix F consists of two questionnaires used by the Task Force in their survey of dust systems in export elevators.

Dust systems in export elevators

Questionnaire No. 1

1. Number of dust systems.
 - a. Bag _____ c. Cyclone _____
 - b. Filter _____ d. Other (specify) _____
 2. For each system specify the following:
 - a. Location _____
 - b. What is done with the dust? _____
 - c. If returned to the grain stream, by what means – i.e., gravity flow, screw conveyer, etc.? _____
 3. If dust is stored, exactly where is the dust bin? _____
 4. If dust is loaded out, how many pounds per week? _____
 5. Who performs the routine maintenance on the dust systems – i.e., checks filters, gauges, etc.? _____
 - a. Specially trained company employees (trained by whom?) _____ c. Contractors _____
 - b. General maintenance staff _____ d. Other (specify) _____
 6. Routine maintenance frequency

	Daily	Monthly	Weekly	As needed
Manometers				
Magnahelic gauge				
Blast gate				
Filters				
Others				
 7. Who performs the major maintenance on the dust system – i.e., duct work, balance, design adequacy, etc.?
 - a. Specially trained company employees (trained by whom?) _____ c. Contractors _____
 - b. General maintenance staff _____ d. Other (specify) _____
- For clarification concerning any problems call:
(FTS) 447-4787

Questionnaire No. 2

- I. Dust systems
 - 1) Number of dust systems
 - 1-5 _____ 11-15 _____
 - 6-10 _____ More _____
 - 2) If dust is partially returned to grain stream, from which systems?
 - A. Unloading facilities
 - 1) Truck dump _____ 3) Barge leg _____
 - 2) Rail dump _____ 4) Other _____
 - B. Gallery _____
 - C. In house
 - 1) Scales _____ 4) Legs _____
 - 2) Cleaners _____ 5) Other _____
 - 3) Boot pit _____
 - 3) If dust is stored, where?
 - A. Inside elevator _____ C. Away from elevator _____
 - B. Adjacent to elevator _____

4) Quantity of dust collected - number of cars/month

- A. 0-3 _____ C. 7-10 _____
B. 4-6 _____ D. More _____

5) Maintenance frequency

	Daily	Weekly	As needed
A. Manometers			
B. Magnahelic gauges			
C. Blast gates			
D. Filters			

II. Dryers

6) Maintenance and cleaning

- A. Daily _____ C. As needed _____
B. Weekly _____ D. Other _____

7) Supervision and monitoring

- A. Constant _____
B. Random _____
C. Never _____

III. Safety

8) Contractors with safety instructions

- A. Written _____
B. Oral _____

9) Equipment H₂O

- A. Hoses _____ C. Back up water _____
B. Pumps _____ D. Employees trained in usage _____

10) Safety meetings for all employees

- A. Monthly or more _____ C. 6-12 mos. _____
B. 1-6 mos. _____ D. Less _____

11) Meetings for management or committee

- A. Monthly or more _____ C. 6-12 mos. _____
B. 1-6 mos. _____ D. Less _____

12) FGIS or state included in meetings?

- A. Monthly or more _____ C. 6-12 mos. _____
B. 1-6 mos. _____ D. Less _____

Table 47.—Dust survey data

Response Areas	FGIS Regions														
	Atlanta (I)			Dallas (III)			Seattle (V)			Chicago (II)			Totals		
	Sample size	Elevator count	Percentage	Sample size	Elevator count	Percentage	Sample size	Elevator count	Percentage	Sample size	Elevator count	Percentage	Sample size	Elevator count	Percentage
1. Dust recirculation															
a. All returned to grain	15	6	40	10	2	20	28	4	14	14	2	14	67	14	21
b. None returned to grain	15	1	7	10	2	20	28	14	50	14	7	50	67	24	36
c. Partial return	15	8	53	10	6	60	28	10	36	14	5	36	67	29	43
2. Dust return sites															
a. Headhouse only	8	0	0	5	0	0	10	0	0	5	0	0	29	0	0
b. Unloading facility	8	2	25	6	2	33	10	7	70	5	2	40	29	13	45
c. Gallery and or spouts	8	0	0	6	0	0	10	0	0	5	2	40	29	2	7
d. Combination of a, b, & c	8	4	50	6	3	50	10	2	20	5	1	20	29	10	35
e. Combination of b & c	8	2	25	6	1	17	10	0	0	5	0	0	29	3	10
f. Other	8	0	0	6	0	0	10	1	10	5	0	0	29	1	3
3. Dust bin location															
a. Inside elevator	9	1	11	8	1	12	23	4	17	12	0	0	52	6	12
b. Adjacent	9	6	67	8	3	38	23	7	30	12	8	67	52	24	46
c. Outside elevator															
1. Less than 50 feet	9	0	0	8	2	25	23	5	22	12	3	25	52	10	19
2. 50–100 feet	9	2	22	8	0	0	23	3	13	12	0	0	52	5	9
3. 101–150 feet	9	0	0	8	0	0	23	2	9	12	0	0	52	2	4
4. More than 150 feet	9	0	0	8	0	0	23	1	4	12	0	0	52	1	2
5. Unknown	9	0	0	8	2	25	23	1	4	12	1	8	52	4	8
4. Dust loaded out (lbs./wk.)															
a. Less than 50,000	9	0	0	8	0	0	24	8	33	12	5	42	53	13	25
b. 50,000–100,000	9	4	44	8	4	50	24	6	25	12	4	33	53	18	34
c. 100,001–150,000	9	0	0	8	0	0	24	4	17	12	1	8	53	5	9
d. More than 150,000	9	1	12	8	2	25	24	0	0	12	0	0	53	3	6
e. Unknown	9	4	44	8	2	25	24	6	25	12	2	17	53	14	26
5. Dust return system															
a. Gravity flow	14	7	50	8	4	50	14	7	50	7	5	71	43	23	53
b. Screw conveyor	14	2	14	8	2	25	14	1	7	7	0	0	43	5	12
c. Pneumatic	14	0	0	8	0	0	14	0	0	7	2	29	43	2	5
d. Combination	14	5	36	8	2	25	14	5	36	7	0	0	43	12	28
e. Unknown	14	0	0	8	0	0	14	1	7	7	0	0	43	1	2
6. Number of systems that do not return dust															
a. 1–5	9	3	33	8	3	39	24	14	59	12	3	25	53	23	43
b. 6–10	9	3	33	8	2	25	24	6	25	12	5	42	53	16	30
c. 11–15	9	0	0	8	1	12	24	2	8	12	4	33	53	7	13
d. 16–20	9	2	23	8	1	12	24	0	0	12	0	0	53	3	6
e. More than 20	9	1	11	8	1	12	24	2	8	12	0	0	53	4	8
7. Total number of systems															
a. 1–8	15	7	47	10	3	30	28	18	64	14	6	43	67	34	51
b. 9–16	15	2	13	10	2	20	28	6	21	14	8	57	67	18	27
c. 17–24	15	2	13	10	2	20	28	0	0	14	0	0	67	4	6
d. 25–32	15	3	20	10	1	10	28	3	11	14	0	0	67	7	10
e. More than 32	15	1	7	10	2	20	28	1	4	14	0	0	67	4	6

Table 47.—Dust survey data — Continued

Response Areas	FGIS Regions														
	Atlanta (I)			Dallas (III)			Seattle (V)			Chicago (II)			Totals		
	Sample size	Elevator count	Percentage	Sample size	Elevator count	Percentage	Sample size	Elevator count	Percentage	Sample size	Elevator count	Percentage	Sample size	Elevator count	Percentage
8. Type of systems															
a. Bag filter	15	10	67	10	4	40	28	24	86	14	10	71	67	48	72
b. Cyclone	15	2	13	10	1	10	28	0	0	14	0	0	67	3	4
c. Combination	15	3	20	10	5	50	28	4	14	14	4	29	67	16	24
9. Location of dust collection systems															
a. Headhouse	15	15	100	10	10	100	28	28	100	14	14	100	67	67	100
b. Gallery/spouts	15	8	53	10	5	50	28	12	43	14	12	86	67	37	55
c. Silos/storage area	15	5	33	10	6	60	28	6	21	14	1	7	67	18	27
d. Unloading facilities	15	13	87	10	10	100	28	22	79	14	13	93	67	56	84
e. Other	15	1	7	10	0	0	28	2	7	14	3	21	67	6	9
10. Routine system maintenance															
Performed by:															
a. Employees trained by:															
1. Manufacturer	15	4	26	10	2	20	28	9	32	14	2	13	67	17	25
2. Engineers	15	2	13	10	0	0	28	2	7	14	4	29	67	8	12
3. Elevator company	15	1	7	10	1	10	28	1	4	14	4	29	67	7	10
4. Other	15	0	0	10	1	10	28	1	4	14	0	0	67	2	3
b. General staff	15	7	47	10	5	50	28	15	53	14	4	29	67	31	47
c. Contractors	15	0	0	10	0	0	28	0	0	14	0	0	67	0	0
d. Others	15	1	7	10	1	10	28	0	0	14	0	0	67	2	3
11. Major system maintenance															
Performed by:															
a. Employees trained by:															
1. Manufacturer	15	1	7	10	1	10	28	9	32	14	2	14	67	13	19
2. Engineers	15	1	7	10	0	0	28	1	4	14	2	14	67	4	6
3. Elevator company	15	0	0	10	3	30	28	1	4	14	0	0	67	4	6
4. Other	15	0	0	10	1	10	28	0	0	14	0	0	67	1	2
b. General staff	15	3	20	10	1	10	28	5	18	14	1	7	67	10	15
c. Contractors	15	9	60	10	4	40	28	8	28	14	8	58	67	29	43
d. Other	15	1	6	10	0	0	28	4	14	14	1	7	67	6	9
12. Frequency of filter checks															
a. Daily	13	7	54	9	3	33	28	13	46	14	4	29	64	27	42
b. Weekly	13	2	15	9	2	22	28	4	14	14	2	14	64	10	16
c. Monthly	13	3	23	9	0	0	28	0	0	14	3	21	64	6	9
d. Unscheduled	13	1	8	9	4	45	28	11	40	14	5	36	64	21	33

U.S. DEPARTMENT OF AGRICULTURE
OFFICE OF THE SECRETARY
OFFICE OF THE SPECIAL COORDINATOR FOR
GRAIN ELEVATOR SAFETY AND SECURITY

GUIDELINES FOR SAFETY OPERATIONS PLANS

I. SAFETY PROGRAM---POLICIES, PROCEDURES, AND INSTRUCTIONS

A. Organization

1. Staff

- a. Designated safety officer and staff members
- b. Responsibilities

2. Safety committees

- a. Members
- b. Responsibilities
- c. Structure
- d. Minutes
- e. Recommendations
- f. Followup
- g. Participation by FGIS
- h. Frequency
- i. Other

3. Plant inspections by management or committee

- a. Frequency
- b. Checklist
- c. Followup procedure

4. Accident prevention

- a. Accident reporting system

(I A)

- b. Accident investigation procedures
- 5. Rule and procedure details (copies to be furnished with the safety operations plan)
 - a. Written plant rules and instructions
 - b. Oral instructions not yet reduced to writing
- 6. Suggestion or incentive program for employee contributions to the plant safety and fire prevention programs.
- 7. Permit procedures
 - a. Welding and/or hot work
 - b. Lockout
 - c. Fumigation
 - d. Bin entry
 - e. Other
- 8. Non-company facility inspections (see Part V, E)

B. Training

- 1. Instructions or handbooks
- 2. Checklists
- 3. General training
 - a. New employee, contractors, and longshoreman orientation
 - i. Precautions
 - ii. Clothing
 - iii. Safety devices
 - iv. Permit procedures
 - v. Other
 - b. Periodic training of employees and supervisors
 - i. Refresher on precautions
 - ii. Clothing
 - iii. Safety devices

(I B)

- iv. Permit procedures
- v. Other
- c. First aid training for at least one employee per shift
 - i. Supervisors
 - ii. Employees
- d. Fire and dust explosion training
 - i. Background
 - ii. Precaution procedures
 - iii. Hazard recognition and response
 - iv. Fire fighting procedures, if applicable
- e. Special hazard training
 - i. Fumigation and pesticides
 - ii. Solvents
 - iii. Other chemicals

C. Personal Safety Equipment

- 1. Head, ear, eye, and nose protection
- 2. Clothing
- 3. Shoes
- 4. Flootation devices

D. Contractors

- 1. Notification of plant safety precautions and procedures
 - a. Contractor management before beginning work on premises and request instruction of contractor's employees at time work is begun.
 - b. Refresher or followup instructions or procedures.

- i. Scope
 - ii. Frequency
2. Supervision of work by responsible elevator personnel
3. Permit procedures
 - a. Welding and/or hot work
 - b. Lockout
 - c. Fumigation
 - d. Bin entry
 - e. Other
4. Inspection at time of completion

II. HOUSEKEEPING

A. Documentation of General Policies

1. Schedules
2. Checklists
3. Instructions

B. Staffing

1. Designated official(s) in charge of housekeeping
2. Each shift
3. Major area where housekeeping staff assigned (headhouse, tunnels, gallery, dock area)

C. Implementation

1. Frequency and scope of inspection
2. Followup of inspections
3. Other supervision measures

D. Other Dust Control Techniques

1. Vacuum (explosion proof)--areas covered
2. Compressed air--used under what conditions
3. Hoses--washdowns
4. Choke feeding
5. Other

(II)

E. Downtime for Housekeeping

1. Dust level established for shutdown
2. Spill level established requiring extra cleanup
3. Shutdown when applicable dust collection system is down
4. General cleanup
5. Other

F. Dust Collection Equipment

1. Number of individual dust systems (filter or cyclones)
2. Disposition of collected dust
 - a. Placed into bin outside complex
 - b. Placed into bin inside complex
 - c. Returned to the grain (number of filters or cyclones)
 - d. Other

III. MAINTENANCE OF MAJOR ELEVATOR EQUIPMENT

A. General

1. Preventive maintenance--scheduled replacement of equipment based upon degree of wear and condition as well as manufacturer's recommendations.
 - a. Written instructions
 - b. Procedures
 - c. Other

(III A)

2. Operational maintenance--normal required operating maintenance.

- a. Written instructions
- b. Procedures
- c. Other

B. Staffing

- 1. Designated official(s) in charge of maintenance
- 2. Designated shift supervisors

C. Vertical Bucket Elevator Legs

- 1. Lubrication and repair records (checklists, schedules, or logs)
- 2. Power source (motor-belts, gear reduction, or chain)
- 3. Controls
- 4. Bearings--rollers
- 5. Tail and head pulleys
- 6. Buckets and belt (checked for alignment, wear, damage, and noise)
- 7. Safety devices (i.e. motion, lockout switches, ammeters)
- 8. Frequency and scope of inspection
- 9. Equipment bonded and grounded
- 10. Other

D. Belts, Trippers, Drags, Screw Conveyors--Written Instructions or Procedures

- 1. Lubrication and repair records (checklists, schedules, or logs)

(III D)

2. Power source (motor-belts, gear reduction, or chain)
3. Controls
4. Bearings--return rollers
5. Head and tail pulleys
6. Drag chains
7. Safety devices (i.e. hot bearing indicators, motion switches)
8. Frequency and scope of inspection
9. Equipment bonded and grounded
10. Other

E. Shipping Gallery, Marine Leg, Dock Area--Written Instructions
or Procedures

1. Lubrication and repair records (checklists, schedules, or logs)
2. Power source (motor-belts, gear reduction, or chain)
3. Controls
4. Head and tail pulleys
5. Bearings--rollers
6. Safety devices (magnetic separators, overload indicators)
7. Frequency and scope of inspection
8. Equipment bonded and grounded
9. Other

F. Dust Systems--Written Instructions or Procedures

1. Lubrication and repair records (checklists, schedules, or logs)

-

(III F)

2. Power source (motor-belts, gear reduction, or chain)
3. Rotary valves, fans, duct work, hoods, blast gates, cyclones and filters
4. Bearings
5. Each system inspected and balanced on a regular basis by a qualified individual
6. Safety devices (manometers, interlocking system with conveying equipment)
7. Frequency and scope of inspection by responsible elevator personnel.
8. Equipment bonded and grounded for static electricity
9. Other

G. Grain Dryers--Written Instructions or Procedures

1. Lubrication and repair records (checklists, schedules, or logs)
2. Power source (motor-belts, chains)
3. Fuel source (oil, propane)
4. Temperature gauges, controls (in control room)
5. Employee assigned to dryer when operating
6. Cleaning schedule
7. Safety devices (sprinkler system in dryer, alarm in dryer, flow of grain to and from dryer automatically shut off in event of fire in dryer)
8. Frequency and scope of inspection
9. Equipment bonded and grounded
10. Other

(III H)

H. Scalpers/Cleaners--Written Instructions or Procedures

1. Lubrication and repair records (checklists, schedules, or logs)
2. Power source (motor-belts, chain)
3. Bearings
4. Cleaning schedule
5. Safety devices (e.g. lockout devices)
6. Frequency and scope of inspection
7. Equipment bonded and grounded
8. Other

I. Scales, Spouting, Distributor Heads, Turn Heads, Sampler Discharge Tubes, Chutes, and Gates--Written Instructions or Procedures

1. Lubrication and repair records (checklists, schedules, or logs)
2. Power source (hydraulic, air, electric, manual)
3. Controls
4. Safety devices
5. Frequency and scope of inspection
6. Equipment bonded and grounded
7. Other

J. Switch Engines--Written Instructions or Procedures

1. Lubrication and repair records (checklists, schedules, or logs)
2. Safety
 - a. Driver training

(III J)

- b. Spark arresters
- c. Fuel tanks checked for leaks
- d. Other

3. Whether switch engine is operated in or through dump area

4. Monitoring operation

5. Other

K. Mechanical Samplers--Written Instructions or Procedures

- 1. Lubrication and repair records (checklists, schedules, or logs)
- 2. Scheduled cleaning (how?--when?)
- 3. Safety devices
- 4. Frequency and scope of inspection
- 5. Equipment bonded and grounded
- 6. Other

L. Tramp Metal Separators--Written Instructions or Procedures

- 1. Repair records (checklists, schedules, or logs)
- 2. Scheduled removal of collected metal
- 3. Tested for effectiveness
- 4. Safety devices (on magnetic separators do belts shutdown when separator reaches its limit or capacity?)
- 5. Frequency and scope of inspection
- 6. Equipment bonded and grounded
- 7. Other

M. Monitoring of Grain Temperature in Silos or Bins

- 1. Type device

(III M)

2. Where installed
3. Monitoring records (logs and schedules)
4. Monitoring procedures
5. Frequency of monitoring

N. Major Electrical Equipment--Written Instructions or Procedures

1. Documentation
 - a. Inspection checklists
 - b. Schedules
 - c. Logs
 - d. Other repair records
2. Approved facility areas for other than Class II Division I environments properly placarded.
3. Control room and auxillary power rooms
 - a. Clean dust from equipment with nitrogen
 - b. Dust-tight
 - c. Frequency and scope of inspection
4. Electrical transformers
 - a. Proper clearance provided for powerlines from pole to transformer for the facility.
 - b. Cables from transformers to control room properly bonded and grounded, and protected from surges/lightning.
 - c. Frequency and scope of inspection for all electrical equipment.
5. Cables, wires, switches, or other electrical equipment
 - a. Dust-tight

(III N)

- b. Bonded and grounded
 - c. Frequency and scope of inspection
- 0. Fire Fighting Equipment
 - 1. Fire extinguishers
 - a. Documentation
 - i. Location chart
 - ii. Checklists
 - iii. Schedules
 - iv. Logs or other service records
 - b. Type
 - c. Frequency and scope of inspection by responsible elevator personnel.
 - d. Frequency serviced
 - 2. Sprinkler system
 - a. Documentation
 - i. Checklists
 - ii. Maintenance schedules
 - iii. Logs or other service records
 - b. Type
 - c. Water supply
 - i. Pumps (capacity, type, etc.)
 - ii. Holding tanks (capacity)
 - iii. Back up system
 - d. Where installed

(III 0)

- e. Frequency and scope of inspection by responsible elevator personnel.
- f. Frequency and scope of tests
- 3. Standpipes and hose stations
 - a. Documentation
 - i. Location chart
 - ii. Checklists
 - iii. Schedules
 - iv. Logs or other service records
 - b. Type
 - c. Frequency and scope of inspection by responsible elevator personnel.
 - d. Frequency serviced
 - e. Frequency and scope of tests
- 4. Water hydrants or wells
 - a. Location (available and readily accessible)
 - b. Frequency and scope of tests
- 5. Alarms
 - a. Central
 - b. Sprinkler
 - c. Intercom
 - d. Fireboxes
 - e. Direct communication to local fire department
 - f. Other
 - g. Frequency and scope of tests

(III)

P. Static Electricity Grounds (Lightning and Equipment Bonding)

1. Documentation
 - a. Location chart
 - b. Logs of test or inspections
2. Inspections and tests
 - a. Frequency of inspection by responsible elevator personnel.
 - b. Tests for effectiveness
 - i. Scope
 - ii. Frequency

Q. Service and Inspection of Safety Equipment

1. Service and inspection records
 - a. Checklists
 - b. Schedules
 - c. Logs
 - d. Location chart for gas masks, self-contained breathing devices, first aid kits, and other safety equipment.
 - e. Other
2. Emergency exits
 - a. Primary
 - b. Alternative means

IV. SECURITY

A. Written Instructions or Procedures

1. Schedules
2. Checklists
3. Logs

(IV B)

B. Staffing

1. Designated officials in charge of security
2. Guards (employees or contract service)
3. Responsibilities
4. Patrols of area or facility
 - a. Scope
 - b. Frequency
5. Hours provided
 - a. Eight hours per day
 - b. Sixteen hours per day
 - c. Twenty-four hours per day--7 days a week.

C. Special Equipment

1. Television cameras
2. Alarm systems
3. Other

D. ID Cards, or Sign-In-and-Out Procedures

1. Employees
2. Contractors
3. Deliverymen
4. Federal Grain Inspection Service
5. Visitors
6. Other

E. Plant or Site

1. Fences (complete or partial)
 - a. Elevator
 - b. Wharf area

(IV E)

2. Other areas (i.e. belt walkways, wharf, headhouse)
3. Methods of securing facility or site during hours when facility is not in operation.

V. EMERGENCY PREPAREDNESS

A. Describe Authority by Which Manager or Superintendent can Shut-down Individual Facility for Hazardous or Emergency Conditions

B. Designated Official in Charge

C. Written Evacuation Plan

1. Supervisory and employee responsibilities

- a. Secure area

- b. Method of exit

2. Tornado procedures

3. Hurricane procedures

4. Bomb threat procedures

5. Fire and explosion fighting procedures

D. Procedures Coordinating Response from Local Authorities

1. Police

2. Fire

3. Civil defense

4. Transportation services

5. Responsible company official designated for emergency preparedness

6. Port authority, Coast Guard

7. Other

E. Inspection of Facility

1. Occupational Safety and Health Administration

2. Fire department--liaison

(V E)

3. Food and Drug Administration
4. Environmental Protection Agency
5. Insurance company
6. Transportation and Warehouse Division
7. Other

F. Emergency Evacuation Drills

1. Regularly scheduled
2. Procedures for natural disasters, fire/explosion and bomb threats
3. Primary and alternative exits
4. Bomb threats

Appendix I

INFORMATION FOR AND ACTION BY: All FGIS Employees
Chief Grain Inspectors
Grain Industry Plant Management

Alert Guideline Procedures and Policies Upon Encountering
"Hazardous Conditions" in Grain Elevators

I PURPOSE

This Instruction:

A Sets forth policies and revised procedures to be followed when major safety hazards are encountered by employees of the Federal Grain Inspection Service (FGIS) while performing official duty in grain, rice, and commodity elevators; mills; and other facilities.

B States hazardous conditions and activities under which Field Office Supervisors may remove Federal employees from the facility.

C States conditions under which Field Office Supervisors may refuse inspection because of prevailing "hazardous conditions and/or activities."

D Is effective immediately upon receipt and will remain in effect until superseded.

II REGULATIONS AND FGIS POLICY

A Regulations. A reference source and the guidelines are those portions of OSHA General Industry Standards (29 CFR 1910), and applicable portions of the National Fire Prevention Codes (57 and 61B). These regulations shall be utilized to determine whether facilities or portions of facilities are considered "unduly hazardous" to FGIS employees.

B Definition. As used herein the term "unduly hazardous" means a situation posing an immediate threat to life, limb, or property.

C FGIS Policy.

1 While "unduly hazardous" conditions are unabated, it shall be within the authority of the Field Office Supervisor to order Federal employees out of the facility and to withhold inspection and weighing until compliance or acceptable progress toward abatement is attained.

2 The FGIS Safety Office with the advice of the OSHA Compliance Office has the responsibility for making the final determinations of "acceptable progress."

DISTRIBUTION: FGIS:IN: 36002, 02029, 02269	MANUAL MAINTENANCE INSTRUCTIONS: This Revision supersedes FGIS Instruction 370-3, dated January 9, 1978. File in the Manual.	Page 1 February 9, 1978
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III "UNDULY HAZARDOUS" CONDITIONS OR PRACTICES

The following list includes, but is not limited to, conditions and practices which constitute a threat to the safety of FGIS employees while performing official duties in grain elevators, mills, or similar facilities, and prescribes the action to be taken.

<u>Condition</u>	<u>Action To Be Taken</u>
1 When the elevator is in operation under the following conditions:	
a When the 10-hour moving average relative humidity is below 45 percent, or the hourly relative humidity is below 25 percent, <u>and</u>	EVACUATE - Alert Field Office Supervisor
b The dust collection system is inoperable, shutdown, or where no dust collection system exists.	
NOTE: The 10-hour moving average relative humidity shall be computed each hour based on the 10 most recent readings. The relative humidity information may be obtained from the nearest National Oceanic & Atmospheric Administration Weather Office. As individual FGIS field offices and elevator laboratories are equipped with suitable devices, the onsite relative humidity data may be used. FGIS employees will resume providing official service when the 10-hour moving average relative humidity rises to 45 percent or above.	
2 Welding, torch cutting, or soldering by anyone.	EVACUATE - Alert Field Office Supervisor
3 Observation of open flames; i.e. lighters, matches, burning cigarettes, pipes, or cigars by anyone.	EVACUATE- Alert Field Office Supervisor
4 The driving wheels of the engine used for positioning railcars are permitted to spin causing sparks while on unloading pit.	EVACUATE - Alert Field Office Supervisor
5 Observation of sparks from foreign objects, or metal parts, or rotating machinery, mills, or grinders, or from nails in shoes.	EVACUATE - Alert Field Office Supervisor

(III)

<u>Condition</u>	<u>Action To Be Taken</u>
6 Observation of electric sparks generated during operations of switches, fuses blowing, damage to cables or equipment.	EVACUATE - Alert Field Office Supervisor
7 Observation of compressed air being used to remove dust from walls and ledges, while elevator is operating.	EVACUATE - Alert Field Office Supervisor
8 Observation of fire or smoke in the headhouse or in grain storage bins.	EVACUATE - Alert Field Office Supervisor
9 The use of portable radios (except regulation Government issue), coffee pots, unapproved electric heaters, or fans by anyone in the open elevator area.	EVACUATE - Alert Field Office Supervisor
10 Excessive fumigant odors.	EVACUATE - Alert Field Office Supervisor
11 Observation of slipping belts on bucket elevators.	Alert Field Office Super- visor
12 Observation of hot surfaces including light bulbs, hot bearings, slipping V-belts.	Alert Field Office Super- visor - Elevator Management
13 Observation of static electricity.	Alert Field Office Super- visor - Elevator Management
14 Observation of moving parts running through dust accumulations or grain spills.	Alert Field Office Super- visor - Elevator Management

(III)

<u>Condition</u>	<u>Action To Be Taken</u>
15 Use of unapproved portable lamps in storage bins.	Alert Field Office Supervisor - Elevator Management
16 Poor housekeeping. (See NFPA 61B, Chapter 7.)	Alert Field Office Supervisor

If the elevator management fails to begin correction of Items 11-16 upon receiving notice, inspection may be withdrawn with concurrence of the FGIS Headquarters.

IV RESPONSIBILITIES

A The Safety Office, Standardization Division, is responsible for:

1 Planning and formulating the major safety and health policies and procedures of the Agency to provide a viable Safety Program.

2 Accident prevention and control, safety education and accident investigation and analysis to determine that FGIS operations are conducted in compliance with applicable OSHA 29 CFR Standards, National Fire Prevention Standards (NFPA) #57 and 61B, and FGIS safety regulations. The address of the Safety Office is:

Safety Office, Standardization Division
Federal Grain Inspection Service, USDA
1400 Independence Avenue, SW
Washington, DC 20250
Telephone: (202) 447-9331

B Supervisors shall:

1 Be on the alert for hazardous conditions.

2 Exercise judgment in actions with safety of FGIS employees being the prime consideration.

3 Immediately contact Elevator Management on actions initiated under Section III, Items 1-10.

4 Immediately contact OSHA Field Office on actions initiated under Section III, Items 1-10.

(IV B)

5 Vigorously enforce all FGIS departmental safety regulations.

6 In questionable situations, time permitting, contact the FGIS Safety Office or the Employee Relations and Services Branch, Personnel Division, Agricultural Marketing Service, for assistance or concurrence.

C Employees shall:

1 Promptly report all hazardous conditions, or unsafe practices to the Field Office Supervisor.

2 Be on the alert for their personal safety.

3 Observe all safety regulations and procedures issued by both FGIS and by the work-site elevator management.

4 Participate in all emergency evacuation drills and safety programs initiated by elevator management.

5 Comply with the safety and conduct requirements set forth in this Instruction.

6 Use personal protective equipment as prescribed.


Deputy Administrator

Appendix J

NUMBERS OF FACILITIES

The following discussion points out discrepancies in the number of U.S. grain handling and processing facilities. The first part analyzes the total number of facilities by starting with the number of grain elevators and deriving the number of feed manufacturing facilities. The second part discusses various estimates for the number of U.S. feed manufacturing facilities and how these estimates were obtained. The estimated number of feed manufacturing facilities is subtracted from the total number of grain handling facilities. This yields a derived figure which should represent the number of grain elevators. The figures derived in the first and second parts of this analysis should be comparable with published estimates. Since this is not the case, it is believed that many grain handling facilities, because they are multiuse facilities, appear on several different listings. This gives the appearance of more U.S. facilities than actually exist.

In 1978, USDA listed 15,065 commercial off-farm grain storage facilities (ref. 10). These storage facilities, by the very fact that in order to store grain they must also be able to receive and load-out grain, also must be classified as handling facilities. As previously stated, NGFA has estimated that there are 9,472 country elevators. In addition, it estimates that there are 413 inland terminals and 82 export terminals (ref. 13); a total of 9,967 grain elevators. Subtracting this figure from 15,065 results in 5,098 other handling/storage facilities.

Additionally, in a 1972 study, the U.S. Department of Commerce cited 729 processing facilities other than feed manufacturers (ref.'s 15, 16). Subtracting this figure from the above 5,098 storage/handling facilities yields 4,369 facilities, a figure which should represent the number of feed manufacturing facilities in the United States.

However, in a 1975 study, USDA cited 6,340 formula feed manufacturing facilities responsible for producing 104.5 million tons of formula feeds;

an estimated 95 percent of the total U.S. production (ref. 16). If the 5 percent of feed production, which was unaccounted for, was manufactured by facilities with the same size distribution as the sample of 6,340, this would yield an additional 334 facilities for a total of 6,674 feed manufacturers in the United States.

In contrast, Shannon and Gerstle, *et al.*, in a 1973 study for the EPA, estimated that there are an additional 4,500 formula feed establishments producing less than 1,000 tons per year (ref. 18). Referring back to the additional 5 percent of feed production not accounted for, if this were added to the surveyed production 104.5 million tons, the estimated total production would be about 110 million tons; a difference of over 5.5 million tons. Now, if all of this additional output had been manufactured by those facilities producing less than 1,000 tons of feed per year, this would yield a figure somewhat in excess of 5,500 feed manufacturers. Presumably, this is the reasoning used by NGFA in estimating a total of 10,840 (6,340 + 4,500) feed manufacturing establishments. Quite obviously, NGFA has assigned a somewhat different size distribution to the facilities responsible for producing the additional 5.5 million tons per year.

Subtracting the above estimate from the 15,065 storage and handling facilities, results in only 4,225 facilities; a figure which should account for all grain elevators and other processors. Assuming that NGFA estimate for the number of country elevators is correct, quite clearly, the figure derived above is far too low.

A possible solution to this dilemma and one which few have mentioned previously, is that many of the 15,065 storage and handling facilities cited by USDA are multiuse facilities. In addition to being grain elevators, many are also feed manufacturers or other processors. Accordingly, any breakdown of grain handling and storage facilities by elevator and feed mill may be misleading.



Appendix K

DEPARTMENT OF AGRICULTURE
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20250

July 18, 1978

The recent series of devastating grain elevator explosions has generated a great deal of concern across the nation and abroad. The grain industry and various Government agencies have increased their efforts within the past 6 months in addressing this problem and seeking viable solutions. Activity at the Federal level has been spearheaded by the Department of Agriculture's Federal Grain Inspection Service (FGIS) and the Department of Labor's Occupational Safety and Health Administration (OSHA).

OSHA's primary responsibility is to ensure the continued safety and health of all persons employed in grain handling facilities. Their efficient enforcement of industry standards relating to grain elevator operating practices is seen as an effective means of achieving this end.

The Department of Agriculture takes a somewhat broader view of the problem of grain elevator safety. FGIS is required by the U.S. Grain Standards Act of 1977, as amended, to "promote and protect the interstate and foreign commerce of grain." Employee safety is, of course, a paramount concern, for without the necessary personnel to perform grain inspection, weighing, and supervision, this responsibility cannot be accomplished. In addition, within the broad confines of the congressional mandate provided by the Act, FGIS has a duty to ensure that the U.S. grain marketing system adequately and effectively meets the demands of both producer and consumer. To this end, we have actively encouraged basic research into the explosive properties of agricultural dusts. Industry researchers are also engaged in inquiries complementing and reinforcing those now being handled by the National Academy of Sciences, the National Institute for Occupational Safety and Health, and the Department's own Science and Education Administration.

Preliminary results obtained from existing research material and from a field survey commissioned by the USDA tend to confirm the commonly held belief that when large amounts of dust in grain handling facilities are coupled with the presence of a number of possible ignition sources, the likelihood of a serious fire or explosion increases.

The Grain Standards Act Advisory Committee, a consultative body comprised of industry, Federal and State officials, at their April 4, 1978, meeting, recommended that dust normally removed during grain handling processes be permanently withheld from the grain stream and considered as an unavoidable loss. The Committee further recommended that, in implementing this action, particle size limits be established for grain dust which would be ultimately removed.

After careful deliberation, the Department of Agriculture, in conjunction with OSHA, and with the concurrence of the Environmental Protection Agency, recommends that dust recirculation be prohibited. This prohibition is a logical and expedient action which could effectively reduce the incidence of grain elevator explosions in the shortest possible time. It would not only better safety and health conditions in grain handling facilities, but also reduce the likelihood of insect infestation.

We strongly urge the grain industry to voluntarily prohibit the recirculation of grain dust in all handling facility dust collection equipment. The Department of Agriculture is now developing particle size standards which would provide guidelines specifying dust which could be safely recirculated. The Department intends to study alternative marketing channels and new product uses which could minimize or negate possible detrimental economic effects resulting from large-scale dust collection.

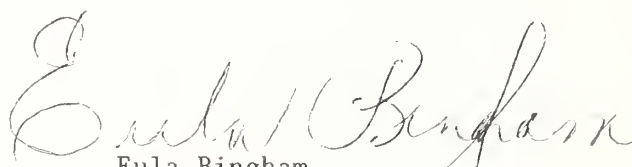
The removal of as much dust as possible from grain handling facilities can only serve to protect and strengthen existing U.S. agricultural export capability while ensuring that industry and Government employees who work in grain handling facilities have a safer and more healthful workplace.

The USDA will continue to reassess this position through evaluation of information presented at the July 11 and 12, 1978, Symposium, as well as results of future research efforts.

Sincerely,



P. R. "Bobby" Smith
Assistant Secretary for
Marketing Services
U. S. Department of Agriculture



Eula Bingham
Assistant Secretary for Occupational
Safety and Health Administration
Department of Labor



UNITED STATES
DEPARTMENT OF
AGRICULTURE

FEDERAL GRAIN
INSPECTION
SERVICE

WASHINGTON,
D.C.
20250

November 15, 1978

To Grain Elevator Operators:

It is imperative that government and grain industry leaders take all reasonable efforts to halt the deadly and costly series of dust explosions that continue to cause such grief and concern across the nation and abroad.

This is not a new or sudden concern. Dust explosions in grain handling facilities have been increasing in both frequency and severity during the past several years. Data collected by the Department's Federal Grain Inspection Service (FGIS) show that 10 grain dust explosions have already occurred this year, resulting in 7 deaths, 47 injuries, and millions of dollars in damages.

The basic causes of grain dust explosions are now sufficiently well known to reduce the number without waiting for additional research. The fine particles of dust collected during the normal handling of grain in elevator systems are extremely explosive. There is a large body of opinion and evidence that elevator operators can greatly reduce their exposure to explosions by adequately collecting the dust and not recirculating these fine particles in the system.

The Grain Standards Act Advisory Committee -- a group of grain industry leaders, Federal and State officials -- recommended in April that the industry move toward withholding the fine dust particles from the grain stream for both safety and quality reasons. During the International Symposium on Grain Elevator Explosions held in Washington, D.C., during July 1978, insurance leaders, scientists, and engineers, including some from the grain industry itself, expressed the view that the threat of explosion can be greatly reduced by not recirculating the fine particles. Later, the Department of Agriculture and the Department of Labor's Occupational Safety and Health Administration (OSHA), with the concurrence of the Environmental Protection Agency, recommended that recirculation of grain dust be prohibited.

Grain Elevator Operators

We believe this recommendation is both logical and in the best interests of the industry. Insurance costs for elevators have skyrocketed in recent years as the number and severity of explosions have increased. Rebuilding elevator facilities following explosions, and the costs of lost production time are also prohibitively expensive.

The USDA will continue to assess the situation as more information becomes available. In the meantime, we urge elevator operators to voluntarily take the logical step and cease the recirculation of dust in the system.

A handwritten signature in dark ink, appearing to read "L. E. Bartelt". The signature is written in a cursive, slightly stylized font.

LELAND E. BARTELT
Administrator

Appendix M

Summary of Mandatory General Industry Standards of the Occupational Safety and Health Administration (OSHA) Which Are Applicable to Grain Elevators

Section	Description	
29 CFR 1910.106	—Handling and Storage of Flammable and Combustible Liquids	29 CFR 1910.151—Medical Services and First Aid
29 CFR 1910.22	—General Requirements (House-keeping, Aisles, Covers and Guard Rails, Passageways, etc.)	29 CFR 1910.157—Portable Fire Extinguishers
29 CFR 1910.23	—Guarding Floor and Wall Openings and Holes	29 CFR 1910.158—Standpipe and Hose Systems
29 CFR 1910.24	—Fixed Industrial Stairs	29 CFR 1910.159—Automatic Sprinkler Systems
29 CFR 1910.25	—Portable Wood Ladders	29 CFR 1910.160—Fixed Dry Chemical Extinguishing Systems
29 CFR 1910.26	—Portable Metal Ladders	29 CFR 1910.169—Compressed Air Receivers
29 CFR 1910.27	—Fixed Ladders	29 CFR 1910.176-.181—Use of Mechanical Equipment for Material Handling and Storage
29 CFR 1910.36	—Means of Egress, General Requirements	29 CFR 1910.212—Machine Guarding Requirements
29 CFR 1910.37	—Means of Egress, Specific Requirements	29 CFR 1910.242—Hand and Portable Power Tools and Equipment
29 CFR 1910.68	—Manlifts	29 CFR 1910.243—Guarding of Portable Powered Tools
29 CFR 1910.95	—Occupational Noise Exposure	29 CFR 1910.244—Other Portable Tools and Equipment
29 CFR 1910.132	—Personal Protective Equipment, General Requirements	29 CFR 1910.252—Welding, Cutting and Brazing Requirements
29 CFR 1910.133	—Eye and Face Protection	29 CFR 1910.309—References the 1971 National Electrical Code, Article 500 (Hazardous Locations) and Article 502 (Class II Locations)
29 CFR 1910.134	—Respiratory Protection	29 CFR 1910.1000—Permissible Exposure Limits to Toxic Chemicals (Including Grain Dust)
29 CFR 1910.135	—Occupational Head Protection	29 CFR 1904.2-.8—Recordkeeping
29 CFR 1910.136	—Occupational Foot Protection	
29 CFR 1910.141	—Sanitation	
29 CFR 1910.143	—Nonwater Carriage Disposal Systems	

SOURCE: "Grain Elevator Industry Hazard Alert," Prepared by the Occupational Safety and Health Administration, January 5, 1978.

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration
WASHINGTON, D.C. 20210



MAY 19 1978

MEMORANDUM FOR: REGIONAL ADMINISTRATORS
AND AREA DIRECTORS/OSHA

FROM: DONALD E. MACKENZIE *D.E.M.*
FIELD COORDINATOR

SUBJECT: Information on Grain Elevator Inspections

The purpose of this memorandum is to obtain uniformity among the 10 regions when issuing citations for alleged violations for grain elevators. A Grain Elevator Task Force was established to review the citations that had been issued, as they were not consistent throughout the 10 regions. In addition, representatives of the industry furnished information regarding problem areas. CSHO's must exercise professional judgement when making a determination and must consider all the conditions existing at the time. The following comments should provide guidance to the field when confronted with similar situations:

A. Items not to be cited:

1. Wood framed screens in shaker operations.
2. Emergency ladders used exclusively as a means of egress from fire and like emergencies that have no safety devices.
3. High level indicators, since motion detection devices are used on the legs.
4. Ferrous tools, such as screw drivers, wrenches, pliers, and mechanical shovels (see enclosed Petroleum Data Sheet dated December 1973).
5. Eight inches of clear space provided between rollers supporting conveyor belts and the floor, to provide access for cleaning.
 - Vacuuming and using air hoses would not require this specific clearance.
6. Compressed air used for cleaning. It can be used if appropriate precautions are taken i.e., all equipment shut down, all sources of ignition removed, and personal protective equipment provided and used.

7. Grain temperature indicators. It appears they provide protection for the product rather than the people.

B. Electrical Requirements:

1. Methods shall be provided to remove static electricity on all equipment, including dust collection systems using material, such as, conductive belts or combs along with bonding and grounding to a common source.
2. In order to establish National uniformity, Sections 502-1 through 502-13 should be grouped together as one item on a citation. Sections 502-14, 502-15, and 502-16 should be cited separately. Sections 502-15 and 110-17 (exposed live parts) in Class II hazardous locations shall be grouped.
3. Use of low voltage battery powered equipment such as flashlights, and "walkie-talkies" approved for Class I, Group D locations in a Class II, Group G area will be considered a technical violation of the standards and handled as de minimis. If units are "intrinsically safe" then no citations will be issued. Non-approved equipment shall be cited.
4. Induction type, totally-enclosed-fan-cooled (TEFC) motors are acceptable for Class II, Division 2 locations.
5. Classification of Area.

Areas should be considered according to the definitions and examples of the NEC. Normally, different areas of an elevator are not classified the same. You may have Class II, Division 1 and 2, and non-hazardous areas in one elevator. The following examples are furnished:

- a. Positive pressurized, well sealed control rooms would not normally be considered a hazardous location.
- b. Properly operated and maintained dust control equipment could change the classification of an area from a Division 1 to Division 2 location. Where evidenced indicates that dust control equipment is not operating properly the area should be classified a Division 1 location. During subsequent discussions with the Area Office regarding the possible declassification of the

area to a Division 2 location, consideration should be given to including an interlock or warning system to assure that the system does not fail again.

- c. Equipment located outside would not normally be considered in a hazardous location, if not adjacent or in vicinity of areas where there is appreciable quantities of grain dust.
- d. We would not cite electrical equipment for hazardous location inside a dryer combustion chamber.
- e. Warehouse areas containing finished packaged products that are well sealed, would not normally be considered a hazardous location, as they do not produce dust.
- f. Generally, caution must be observed when classifying from the NEC. We must still identify the specific hazard associated with a given condition. Conditions may exist that change the classification from one class to another or to a non-hazardous location.
- g. To properly evaluate an area as to hazard classification, the CSHO must obtain and record at least the following information:
 - 1. The specific sources of dust, e.g., open transfer points, open conveyer, open bin, or hopper, leaking leg, etc.
 - 2. Actual measurements (so many inches, feet, etc.) showing the amount of dust accumulations.
 - 3. Estimate on how fast the dust accumulates.
 - 4. Visual observations as to the density of dust in the air.

C. The following items will be cited under the General Duty Clause, Section 5(a)(1)

- 1. Motion Switches. There shall be a method to warn and finally shut down the elevator leg and all contributing conveyors at a predetermined speed. An alarm shall sound at 15% and shut down at 40% reduction of full load speed.

Possible devices are:

- a. Device on the head or knee pulleys,
- b. Belt specially built to separate at temperatures below that required to ignite grain dust; and,
- c. Any other equally effective device.

2. Bearings. Rabbit bearings, as such, are not prohibited. Cite only when they are not properly lubricated and maintained by a good maintenance program. Similarly, ball or roller bearings need inspection, since they too, need proper maintenance procedures. Improper maintenance and lubrication can cause overheated bearings. Check for damaged seals from over greasing, lack of lubrication, overheated bearings, etc.
3. Venting. Elevator legs not provided with explosion venting to the outside atmosphere. Dust collectors shall also have venting to the outside atmosphere with proper type explosion panels. On new construction, elevators should incorporate the principles of explosion venting in the design of the facility.
4. Railroad Engines. Railroad engines present a hazard where sparks are emitting from the stack, dust is present in the hot engine area, accumulations of dust are present, sparks could fall into the pit, or other conditions exist that could ignite grain dust.
5. Metal grain buckets are acceptable. However, if there are loose or broken buckets, or improper leg belt alignment, those conditions should be cited.
6. Tramp metal. At grain receiving areas (the requirements at processing machinery would be different) magnets, screens with 1½ inch maximum openings, or other effective means shall be provided for removal of tramp metal. Depending on the type of grain being received, the screen openings may be slightly smaller or larger.

D. Other Comments:

1. Grain dust. Organic dust is citable under Table Z-3.
2. Cite 1910.106 for the storage of flammable or combustible materials.
3. Normally citations will not be issued for front end loaders being used in barges, flat type storage buildings and warehouses, unless a specific Class II hazard can be identified. Steel and other types of tanks could present a hazard and should be evaluated individually as to appropriate hazard classification. Recommend citing 1910.178 as applicable and in the alternative Section 5(a)(1) as a single item.

4. Monitoring bin and confined spaces prior to entry. Citations shall be issued for lack of testing to assure that no harmful residues remain, where grain has been held in storage structures under fumigation or pesticide treatment. Where appropriate natural ventilation has been utilized in dry grain storage, we would not cite for monitoring of oxygen levels.
5. For grain dust accumulation, cite both 1910.22(a)(1) and Section 5(a)(1) as one item, typing the statement "in the alternative" on the citation between the two sections.
6. Internal Combustion Engines regarding farm tractor and truck operations, at this time, they appear not to present the same hazards as railroad engines.

PROGRAM REVIEW REPORT

June 27, 1978

USDA-Science and Education Administration
Federal Research Program
for
Systematic Study of Explosion, Control, Handling
and Utilization of Grain Dust
U.S. Grain Marketing Research Laboratory, Manhattan, Kansas

This program is a part of NRP 20590, Technologies for Marketing Field Crops.

Technological Objective: Develop new and improved technologies for protection of health and insuring safety in the grain elevator environment and for reducing the incident and severity of explosions in grain handling facilities.

Visualized Technologies: Systems for early detection, warning and suppression of developing adverse conditions leading to potentially hazardous environments. Methods for reduction of dust created in handling, transportation, and storage of grain. Improved housekeeping technologies.

Major Research Approaches:

- I. Literature review and critical engineering analysis to identify useable technologies not currently applied in grain handling industries and parameters leading to hazardous environment.
 - A. Survey of incidence
 - B. Detection of flames and explosions
 - C. Initiation of explosions
 - D. Propagation of explosions
 - E. Explosion effects

Investigator: Mr. David Aldis - Work has almost been completed and report is in preparation. It is considered important that a continuing review of publications in the field be made available and an information newsletter containing abstracts of dust explosion research is to be initiated.

Approximately 3/4 SY effort currently is being devoted to this work but could be reduced for a continuing information newsletter.

- II. Control and Minimization of Grain Dust Generation and Accumulation.
 - A. Grain handling to minimize dust emission
 - B. Use of additives
 1. Type and mode of application
 2. Evaluate grain cleaning methods
 - C. General housekeeping techniques
 - D. Pilot scale applications

Investigators: Mr. Charles Martin and Dr. F. S. Lai - Sampling and analysis of grain dust from elevators is already showing results with implications for enhanced utilization. The particulate size classification effect of collection systems is being investigated. Removal of non-combustible portion of the dust which is principally in the fines, leaves the rest of the material more nearly equivalent to grain in feed value. Three elevators and four types of dusts collected at different locations in the elevators and four different grains have been studied so far.

Additives for reduction of dust are being examined, water and vegetable oil initially. Plans call for the materials to include guar gum, pre-gelatinized starch, and food-grade additives.

III. Characterization and Classification of grain dusts from different grains to provide basic data related to explosibility, health, and utilization.

- A. Physical-particle size distribution, surface area, density
- B. Chemical-protein, ash, moisture fat, fiber, starch, heavy metals, mycotoxins
- C. Physiochemical-heat of combustion, explosibility

Investigators: Dr. John C. Matthews, Chemical Engineer, KSU - Sorption of gases (methane, CCl_4 , CS_2), surface area, pore size distribution, and void volume of dust. Dr. F. S. Lai, USGMRL - $\text{H}_2\text{O}:\text{RH}$ equilibria.

Much of the data from other investigation will contribute to this part of the program. Dr. Matthews of the Chemical Engineering Department at Kansas State University is acquiring some very basic particulate characterization data which will allow subsequent evaluation of the effects of fumigants and for possible measurement of grain dust parameters related to explosive conditions in elevators.

Dr. Lai's work on dust moisture content and air humidity equilibrium phenomon relates directly to the relationship of RH to elevator explosion hazard.

Approximately 1 SY is being used in this work.

IV. Mechanism of Explosions and Base-line Explosibility Data

- A. Bench scale explosion tests
 - 1. Bureau of Mines tests
 - Minimum ignition temperature
 - Maximum ignition energy
 - Maximum pressure rise
 - Maximum rate of pressure rise
 - Minimum concentration of dust and particle size distribution
 - 2. Evaluation of alternative tests

3. Effects of additional factors
 - Relative humidity
 - Chemical composition
 - Miscellaneous
4. Effect of ignition source
 - Spark duration
 - Electrostatic charge
 - Source ignition
 - High temperature
- B. On-site survey of dust generation, concentration, composition, and environmental conditions
 1. Elevator open space
 2. Within equipment and bins
- C. Pilot scale explosion tests
 1. Effect of container shape and size
 2. Experimental analysis of the transition from a deflagration to a detonation
 3. Simulation studies

Investigators: Dr. F. S. Lai, USGMRL. Bench scale dust explosion tests

- Minimum ignition temperature
- Minimum ignition energy
- Maximum pressure rise
- Maximum rate of pressure rise
- Minimum concentration of dust and particle size distribution

Dr. Tom W. Lester, Nuclear Engineer, KSU, Chemical shock tube research and mechanism of dust explosions

Dr. Ronald S. Lee - Physics, KSU, Modeling of dust explosion.

Contracts with other Kansas State University departments are underway. It has been found that previous shock tube study techniques are applicable to grain dust. An important element in this portion of the program is in simulation of explosive hazard.

"Combustion processes encompass a wide range of physical phenomena. While a phenomena like a dust explosion might seem hopelessly complex, the physical principles which govern the explosion are the laws of hydrodynamics and thermodynamics. For idealized geometrics it is possible to numerically solve the partial differential equations which describe the interaction of a dust cloud with an ignition source and the combustion wave which might subsequently occur. Dr. Ron Lee of the Department of Physics at KSU is currently investigating two types of simulations that might be of value in understanding dust explosions.

"The first type of simulation he wishes to explore is the interaction of an electric spark with a surrounding gaseous medium. It has been experimentally demonstrated that short duration ($< 1 \mu$ sec) sparks are less effective in igniting dust clouds than longer duration sparks. The reduced effect of the short duration sparks is believed to arise from transport of dust particles out of the region near the spark by the hydrodynamic flow associated with a short duration spark. From the numerical solution of the hydrodynamic flow, he will attempt to estimate the rate of transport of the dust particles.

"The second type of simulation which would be useful in studying dust explosions is the interaction of a dust cloud with a heated surface. A one-dimensional combustion code, which has recently been developed at Lawrence Livermore Laboratory, is capable of handling such a simulation. This type of simulation would be useful for interpreting the results of our laboratory explosibility experiments and in predicting the results of changes in experimental parameters.

"Numerical simulations are a powerful tool in the study of thermohydrodynamic phenomena. Simulations can help identify the important parameters in an experiment, and the feedback loop between simulation and experiment can add greatly to the understanding of the phenomena being studied."

V. Development of Remote Electronic Monitoring and Data Processing Systems for Detection, Warning and Initiation of Suppression Action.

- A. Particle size distribution and concentration in situ
- B. Humidity, temperature, static electric potential
- C. Dust layer accumulation
 - 1. Elevator open space
 - 2. Within equipment
- D. Other parameters

Investigators: Mr. Jon Held - Construction of a device to determine rapidly (in a millisecond) the dust concentration and particle size distribution in situ, based on laser beam interference phenomenon is underway.

VI. Utilization of Grain Dust.

Research to improve potential utilization of grain dust is seen as a necessary step to economic incentive for removal of dust from grain which could have major impact on elevator safety. Several investigators will contribute to this work.

Investigators: Dr. Karl Norris, SEA/FR - Rapid determination of nutritive value using near infrared analysis.

Dr. L. D. Schnake, USGMRL, KSU - Economic feasibility study of mobile and stationary pelleting and extrusion of dust

Mr. Charles Storey, USGMRL - Residual CS₂ from fumigation.

Dr. Larry E. Erickson, Chem. Engr. Dept., KSU - Single cell protein production; prediction of nutritive value; use in combination with spent grains.

Mr. John Hubbard, USGMRL - Amino acid analyses

Mr. Charles Martin, USGMRL - Proximate analysis, element (metal) composition, and physical characteristics of wheat, corn, sorghum and soybean dust collected at selected locations in elevators. Heat of combustion using N,C,H,O,S analysis data.

Dr. C. Chang, USGMRL - Utilization of dust by: (1) burning, (2) composting.

Dr. F. S. Lai, USGMRL

Various portions of this work is in progress.

VII. Evaluation of Factors in Grain Structure, Composition, and Handling which Affect Explosibility

- A. Genetic studies
- B. Grain resilience
- C. Grain composition
- D. Grain history - drying, handling, etc.

This part of the research is of longer term and has not yet been initiated.

Appendix P

Summary of Other Standards Referenced in NFPA No. 61-B

Standard Number	Description		
NFPA No. 10	Installation of Portable Fire Extinguishers	NFPA No. 66	Pneumatic Conveying Systems in Handling Feed, Flour, Grain, and Other Agricultural Dusts
*NFPA No. 13	Standard for the Installation of Sprinkler Systems	NFPA No. 68	Guide for Explosion Venting
*NFPA No. 14	Standard for the Installation of Standpipe and Hose Systems	*NFPA No. 69	Explosion Prevention Systems
*NFPA No. 15	Water Spray Fixed Systems for Fire Protection	NFPA No. 70	National Electrical Code, Articles 500 and 502
NFPA No. 30	Flammable Liquids Code	*NFPA No. 72 A	Local Protective Signaling Systems
NFPA No. 31	Standards for the Installation of Oil Burning Equipment	*NFPA No. 72 C	Remote Station Protective Signaling Systems
NFPA No. 51 B	Standard for Fire Protection in Use of Cutting and Welding Processes	NFPA No. 77	Recommended Practice on Static Electricity
NFPA No. 54	Standard for the Installation of Gas Appliances and Gas Piping	NFPA No. 78	Lightning Protection Code
NFPA No. 57	Standard for Fumigation	NFPA No. 86 A	Standard for Ovens and Furnaces
NFPA No. 58	Storage and Handling of Liquefied Petroleum Gases	NFPA No. 91	Installation of Blower and Exhaust Systems
		NFPA No. 490	Storage of Ammonium Nitrate
		NFPA No. 601	Recommendations for Guard Services in Loss Prevention

*Referenced in the Appendix included with Standard No. 61-B.

SOURCE: "Standard for the Prevention of Fire and Dust Explosions in Grain Elevators and Bulk Grain Handling Facilities," NFPA No. 61-B, 1973.

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